Boeing Technology
Phantom Works

Tracer Diffusion in Whisker-Prone Tin Platings

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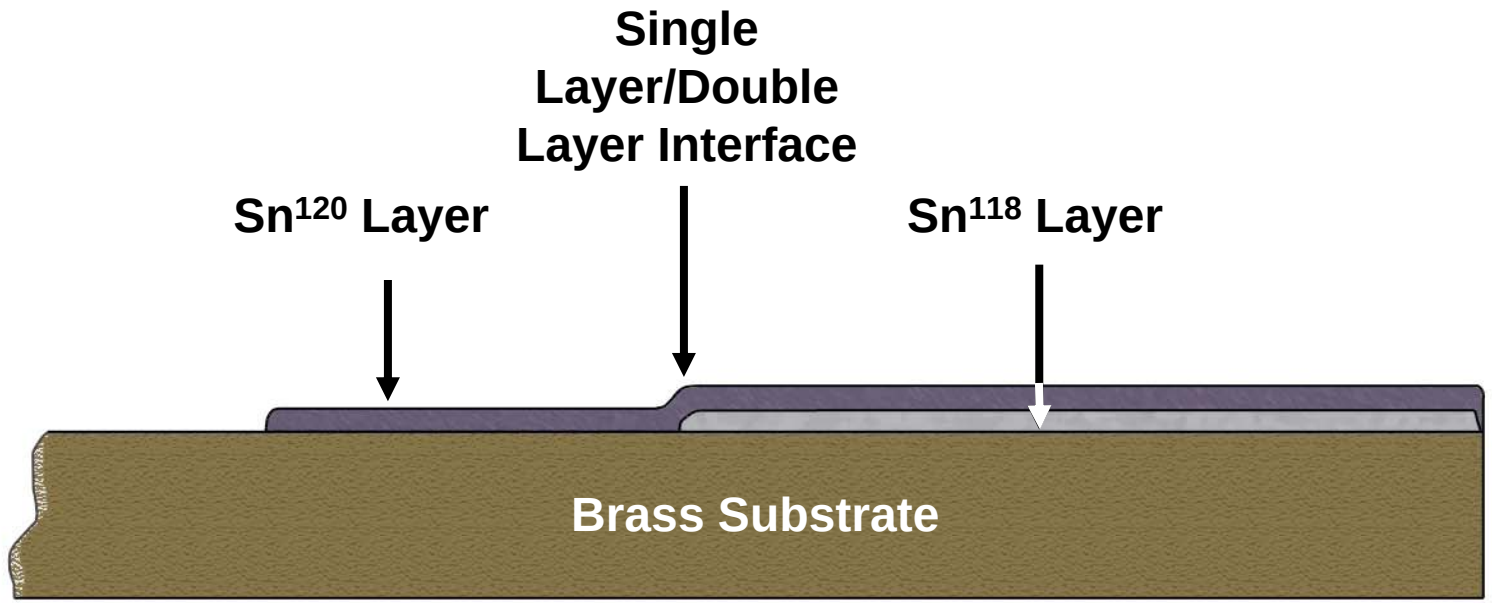
- **After 60 years of tin whisker research, little is known about diffusion in whisker-prone tin platings.**
- **Where does the tin in a whisker come from?**
- **Does the tin reach the whisker through the lattice, through the grain boundaries, or across the surface?**
- **Does a surface oxide layer inhibit diffusion?**

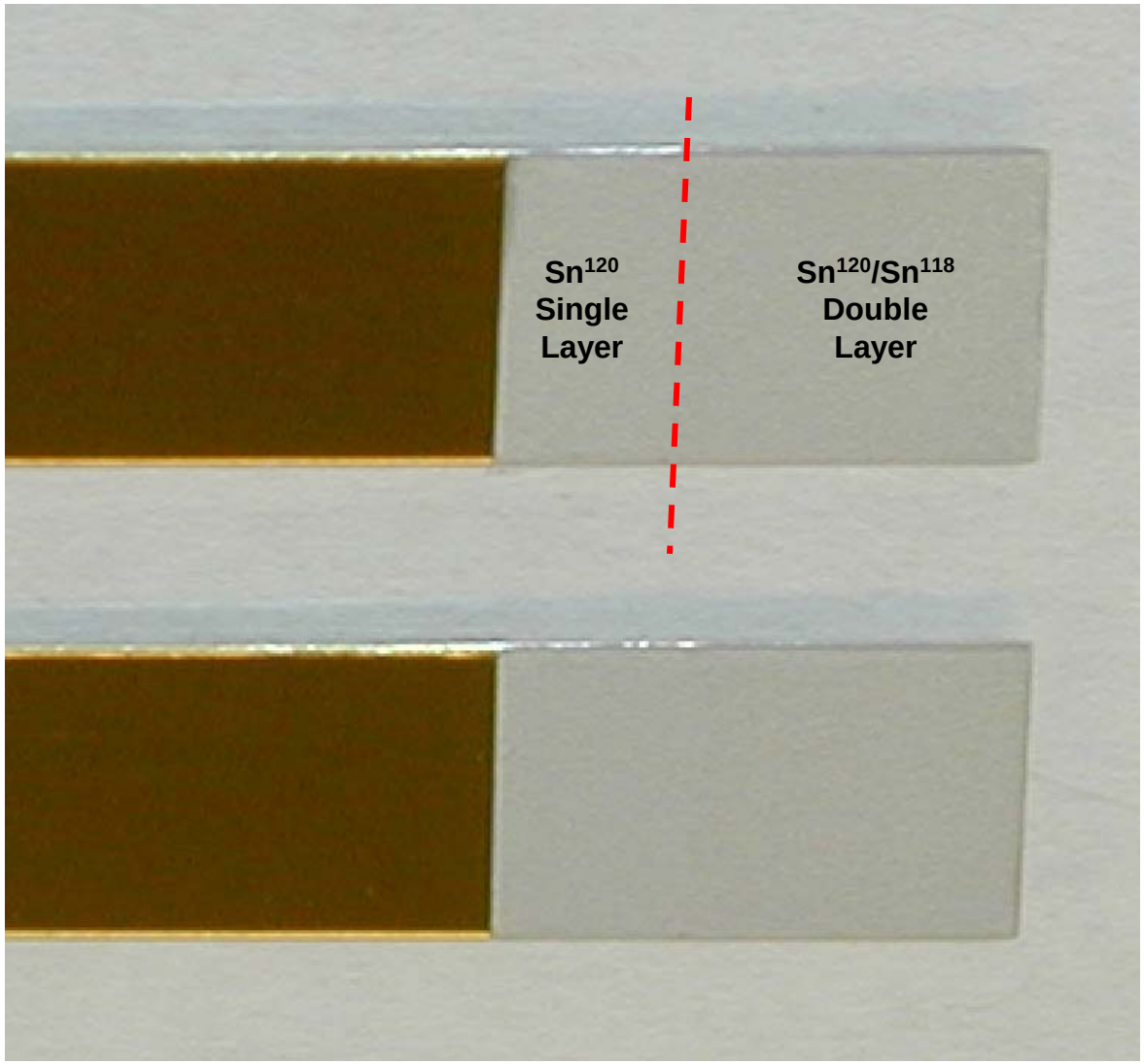
- **Non-radioactive isotopes can be used to track the diffusion of tin in a tin plating.**

Test Coupon

- **Electroplated Sn isotopes onto brass substrates**
- **Bright and matte Sn platings**



Test Coupons (Matte Sn)

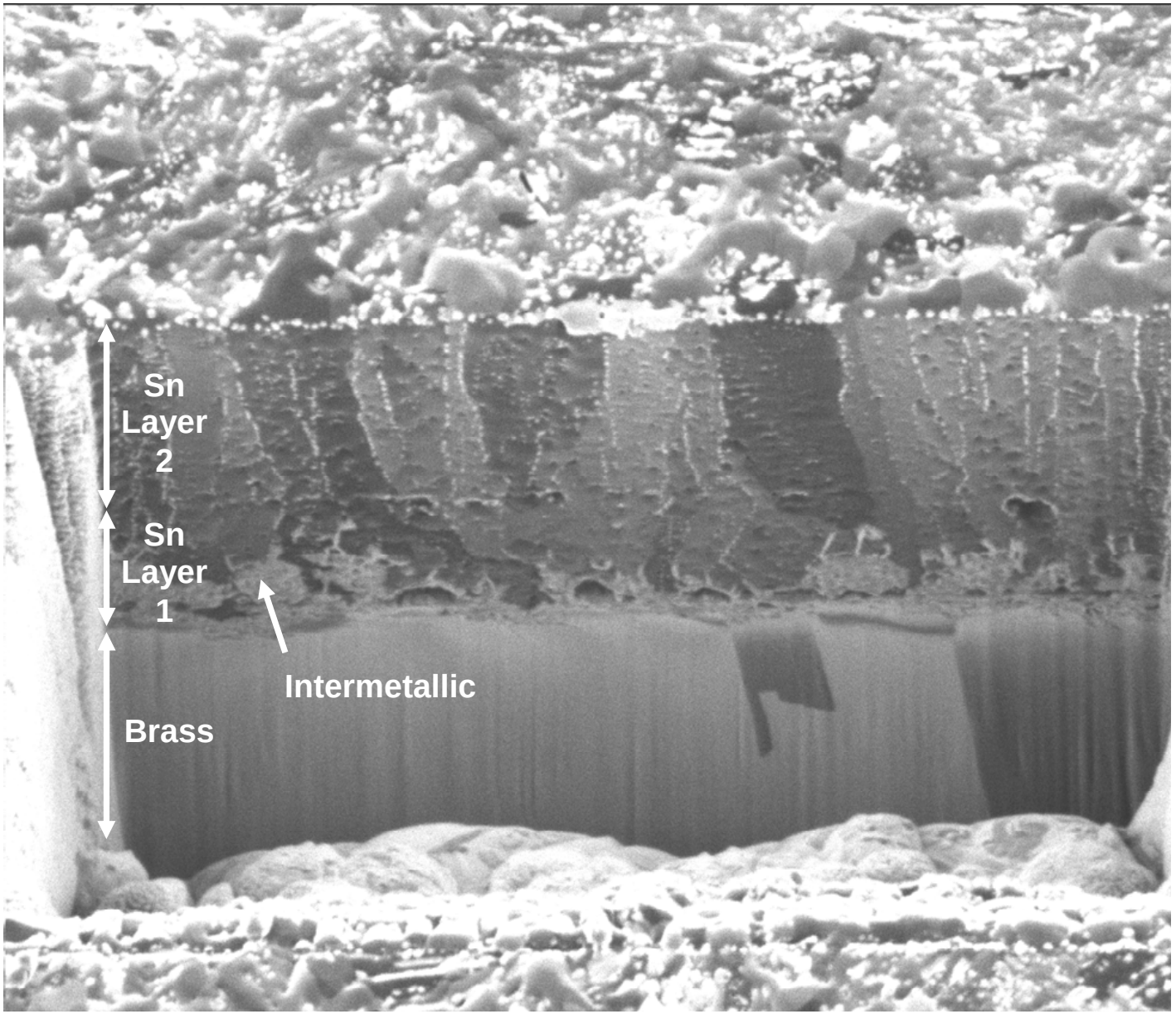


Isotopic Purity of Anodes

	Relative Percentages of Tin Isotopes	
Isotope	**Sn^{120} Anode**	**Sn^{118} Anode**
Sn^{124}	0.02	0.1
Sn^{122}	0.06	0.1
Sn^{120}	**99.6**	**0.5**
Sn^{119}	0.13	0.3
Sn^{118}	**0.13**	**97**
Sn^{117}	0.02	1.8
Sn^{116}	0.04	0.2
Sn^{115}	0.00	0.0
Sn^{114}	0.00	0.0
Sn^{112}	0.00	0.0

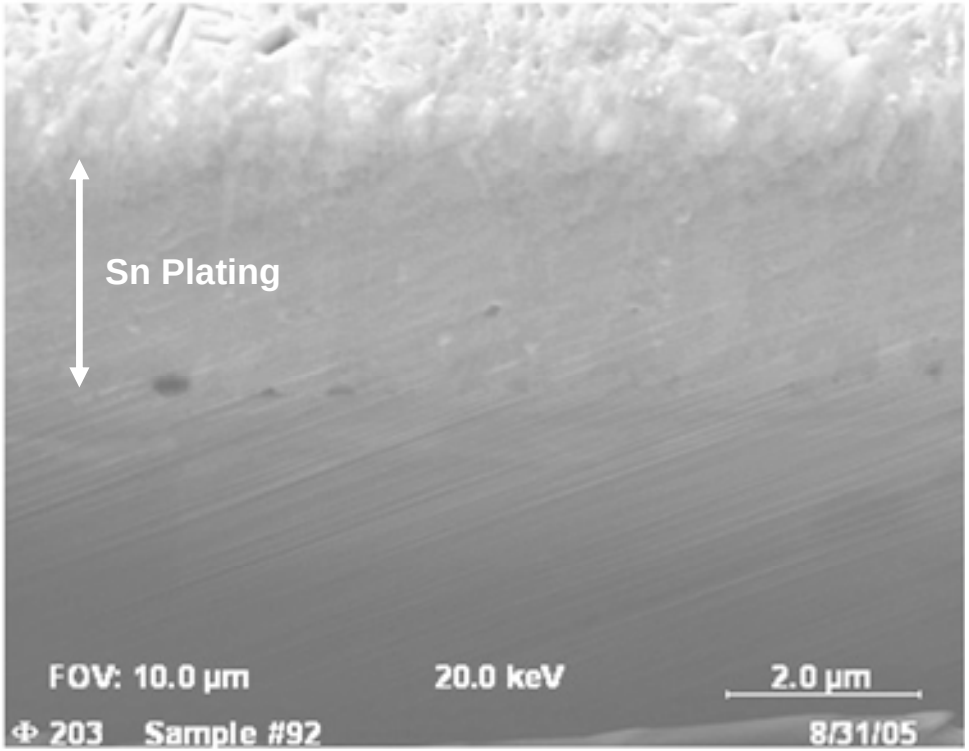
FIB Microsection (Bright Sn Plating)

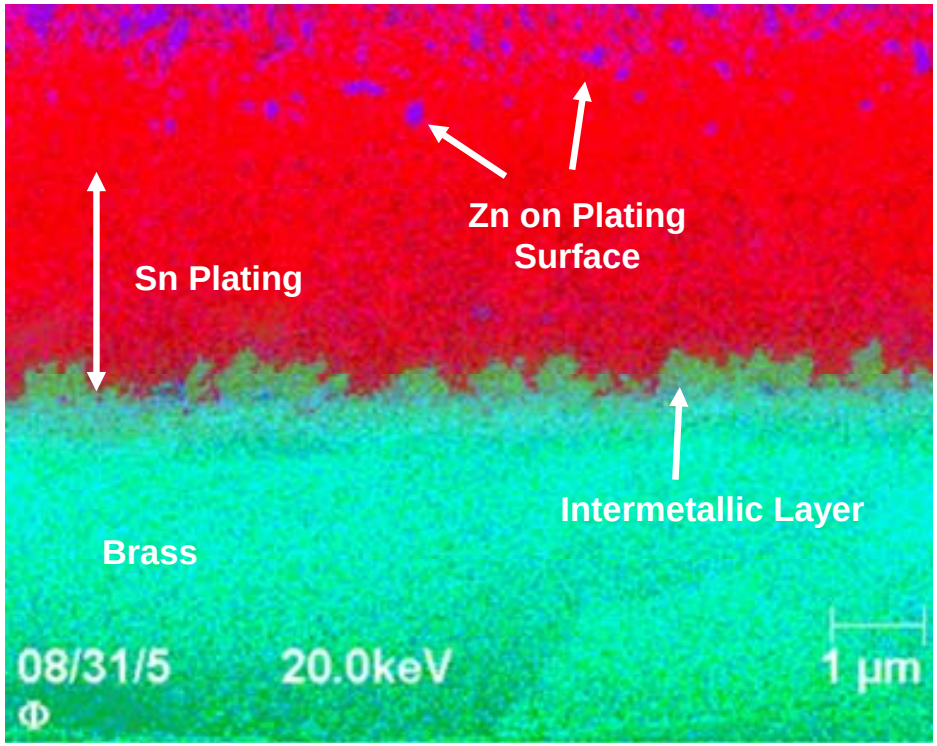
109 Days after Plating



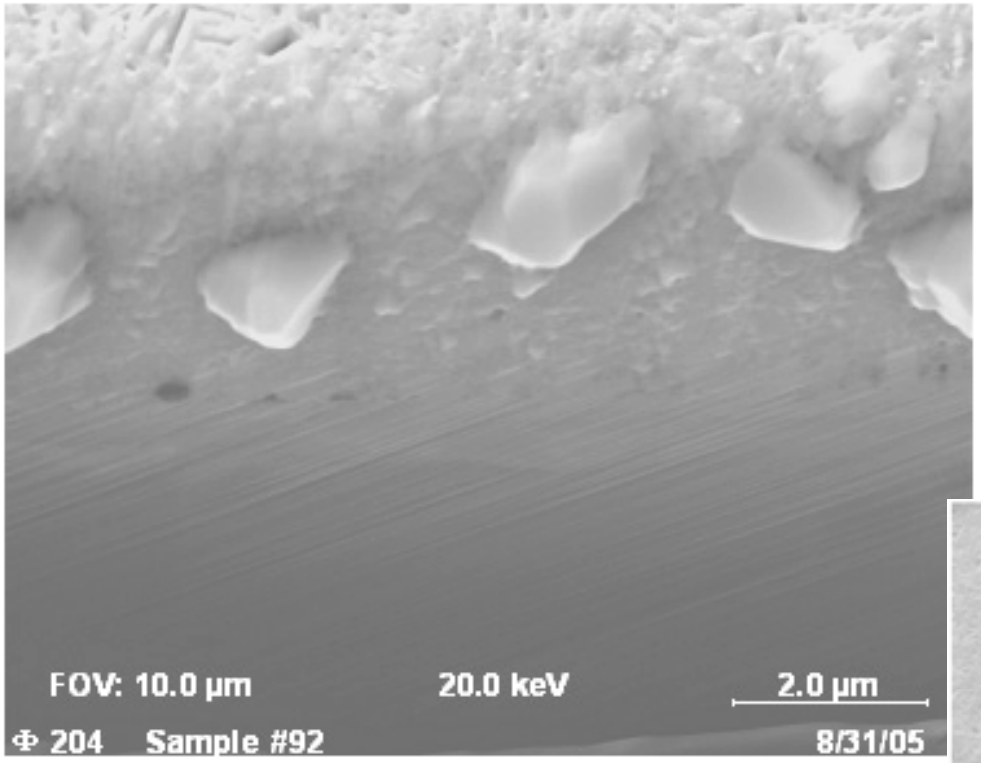
Auger Analysis of FIB Microsection (Bright Sn Plating)

67 Days after Plating

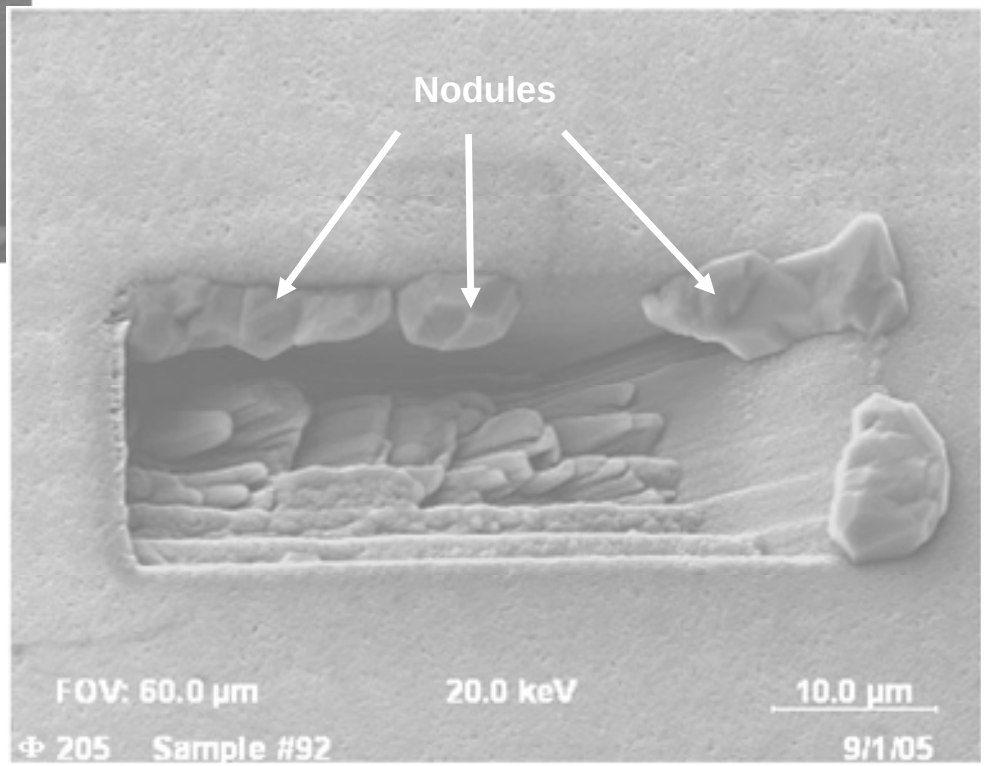




Nodules Forming on FIB Microsection (Bright Sn Plating)

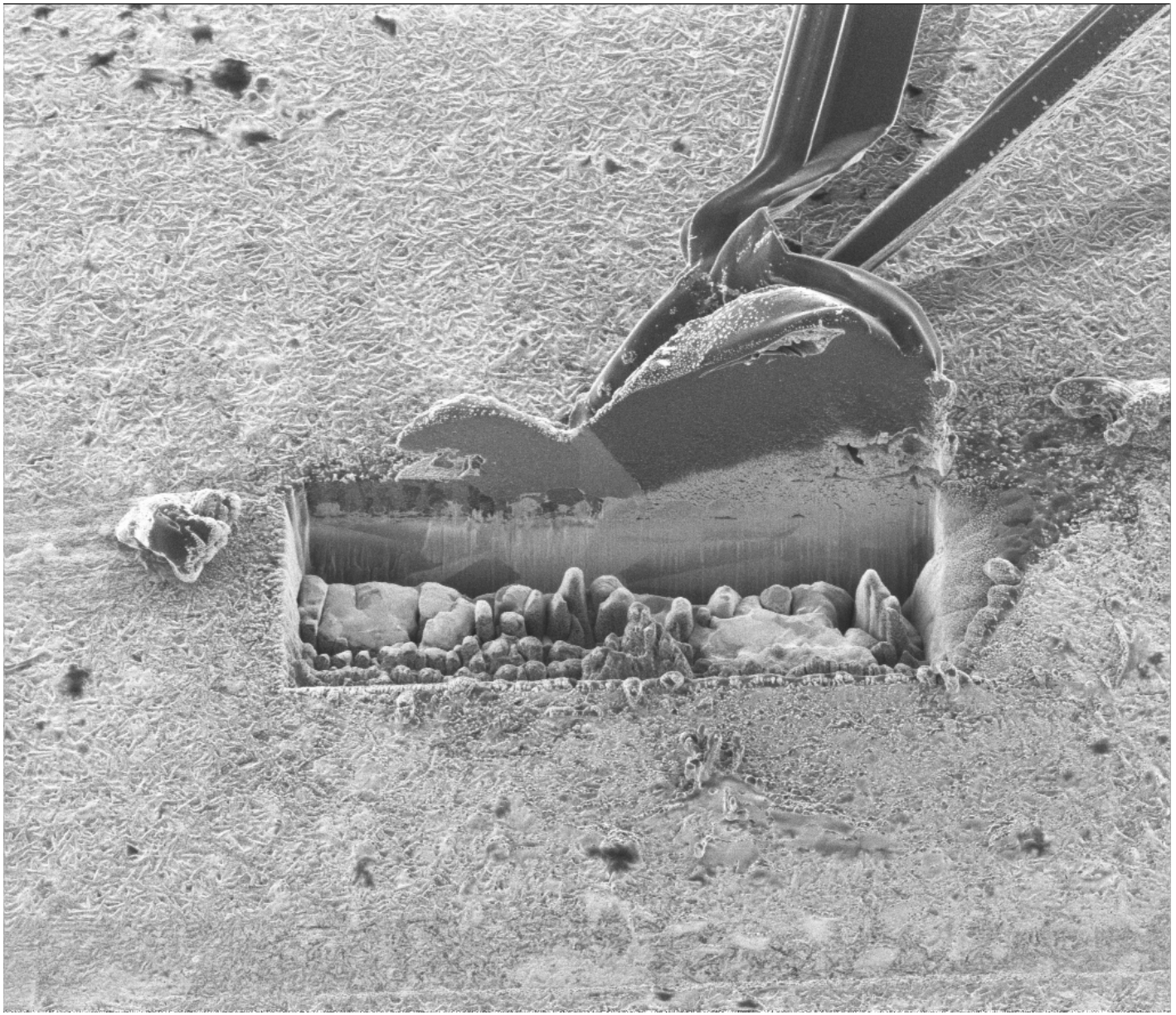


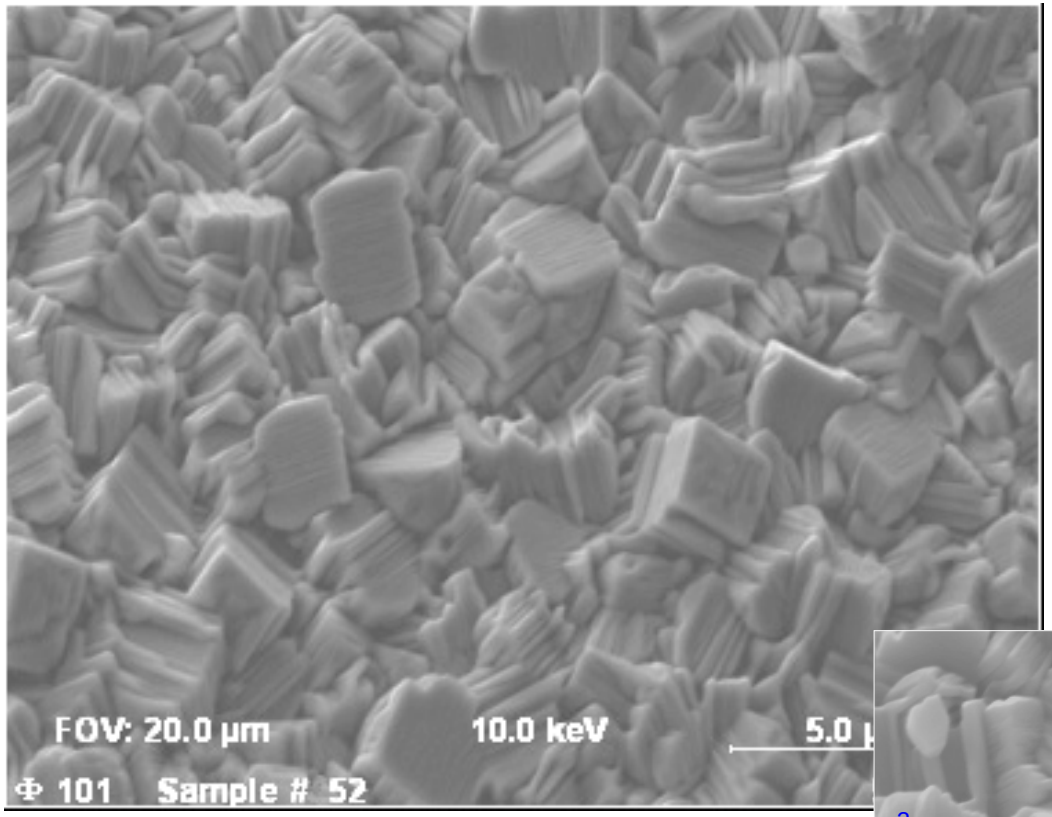
30 Minutes after FIB Cut Was Made



18 Hours after FIB Cut Was Made

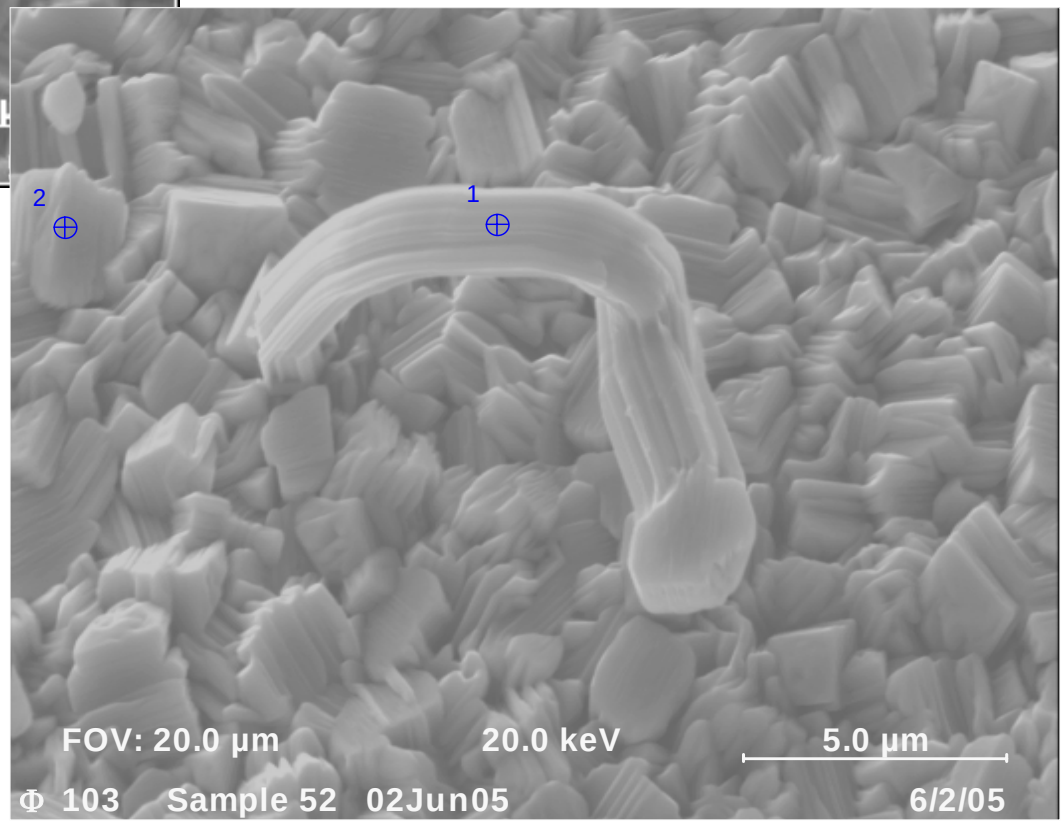
FIB Microsection of Nodule on Bright Sn Plating





Matte Sn Plating Surface

10 Days after Plating

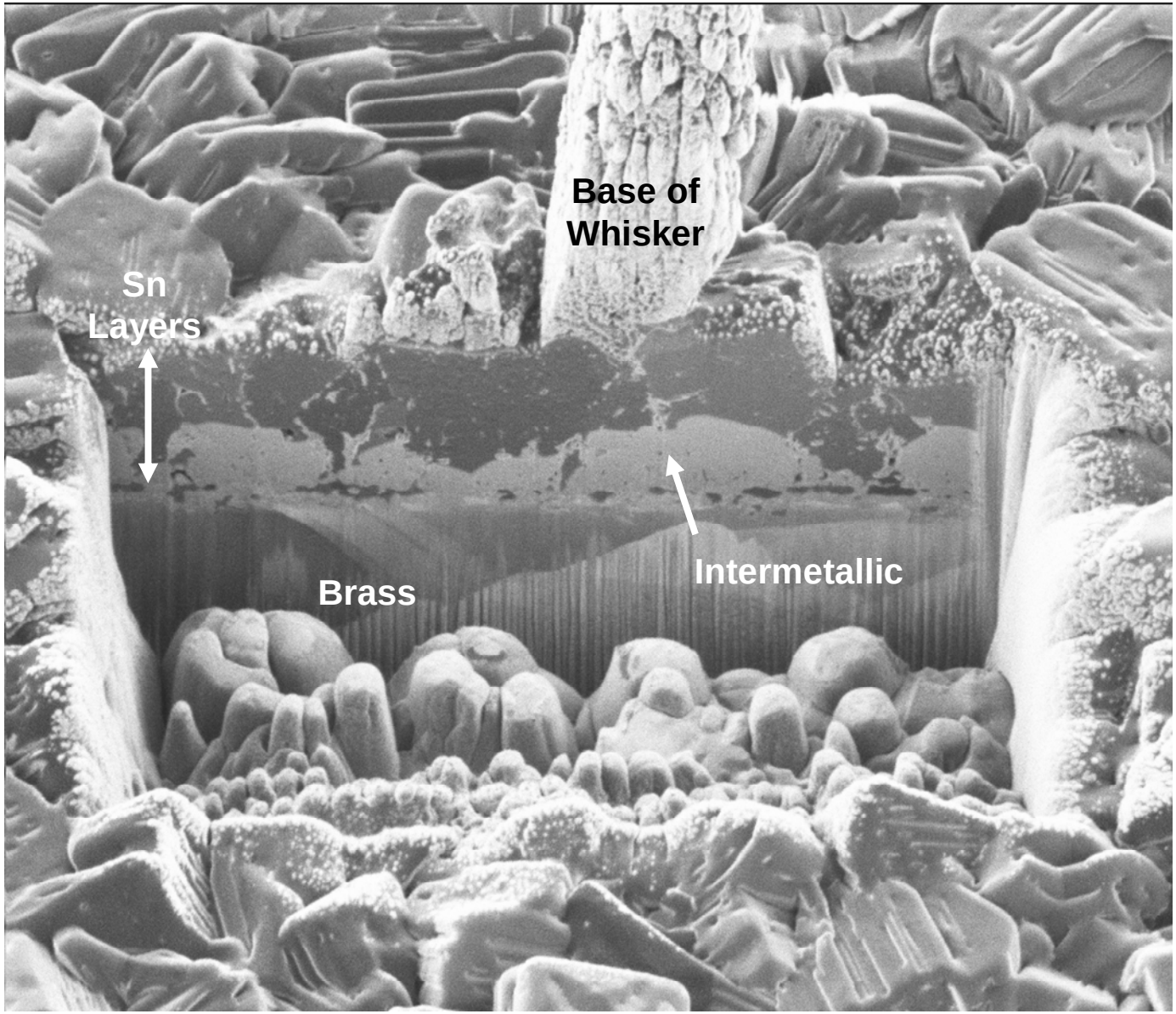


Whisker on Matte Sn Plating Surface (No Nodule Formation)

26 Days after Plating

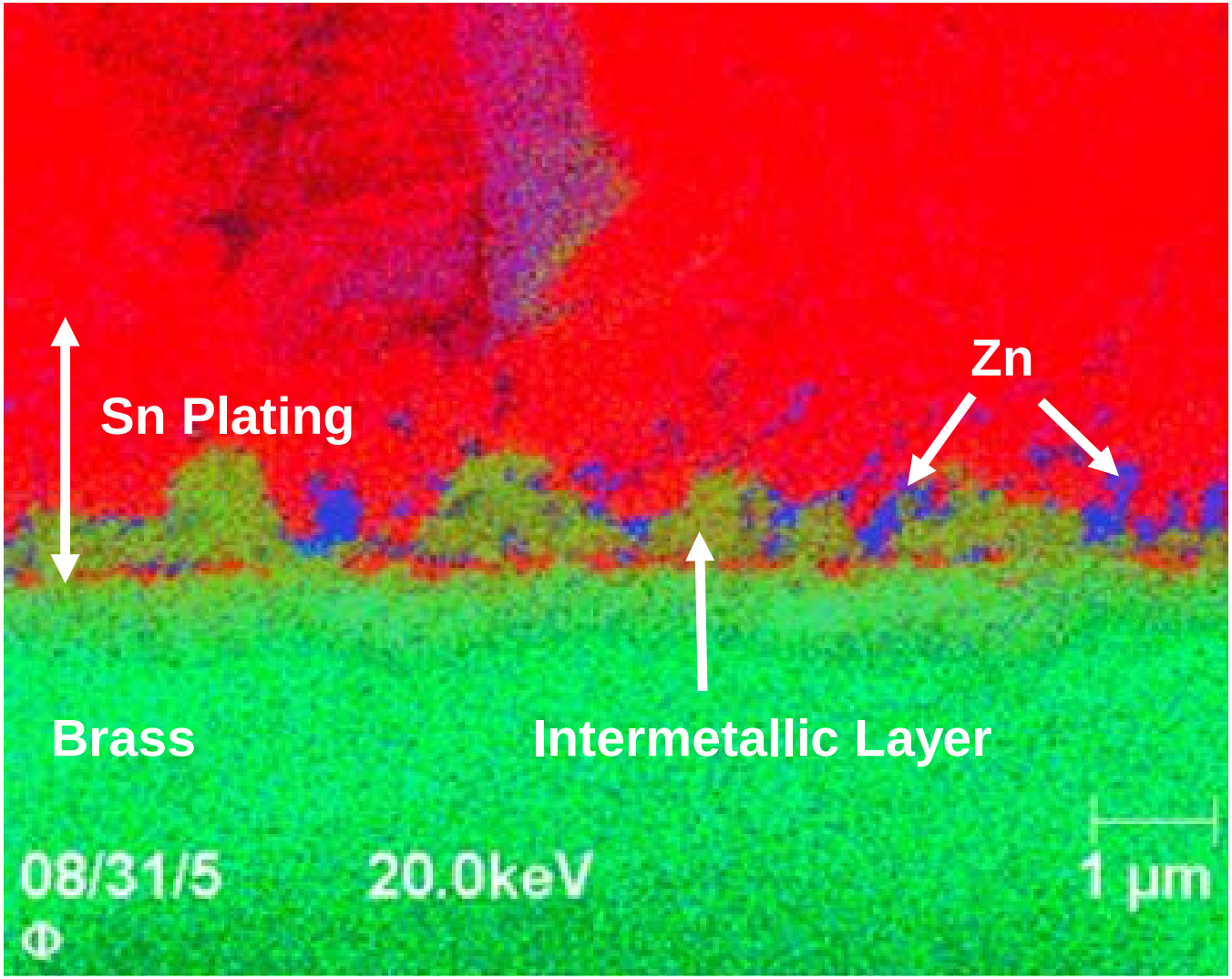
FIB Microsection of Matte Sn Plating

158 Days after Plating

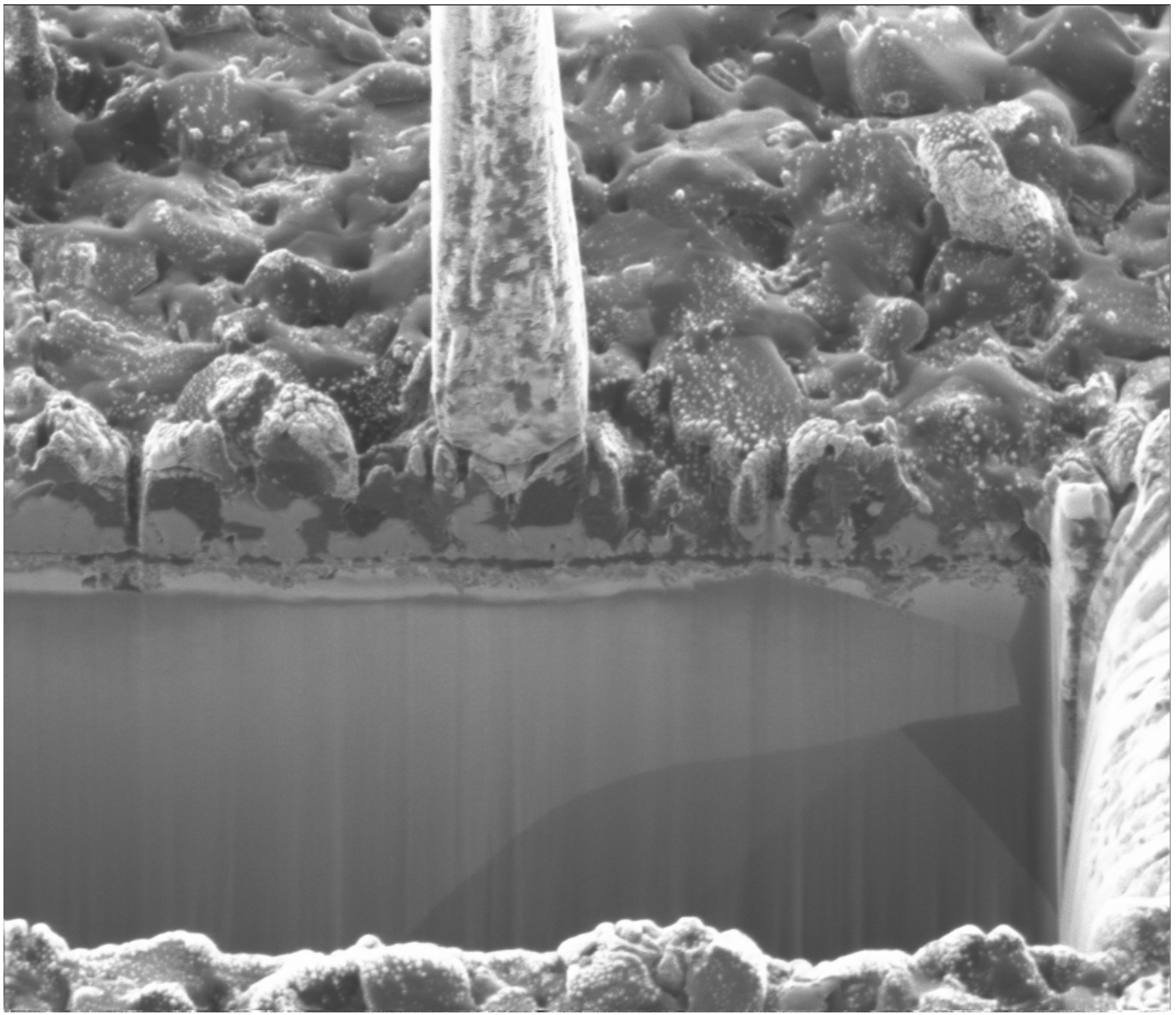


Auger Analysis of FIB Microsection (Matte Sn Plating)

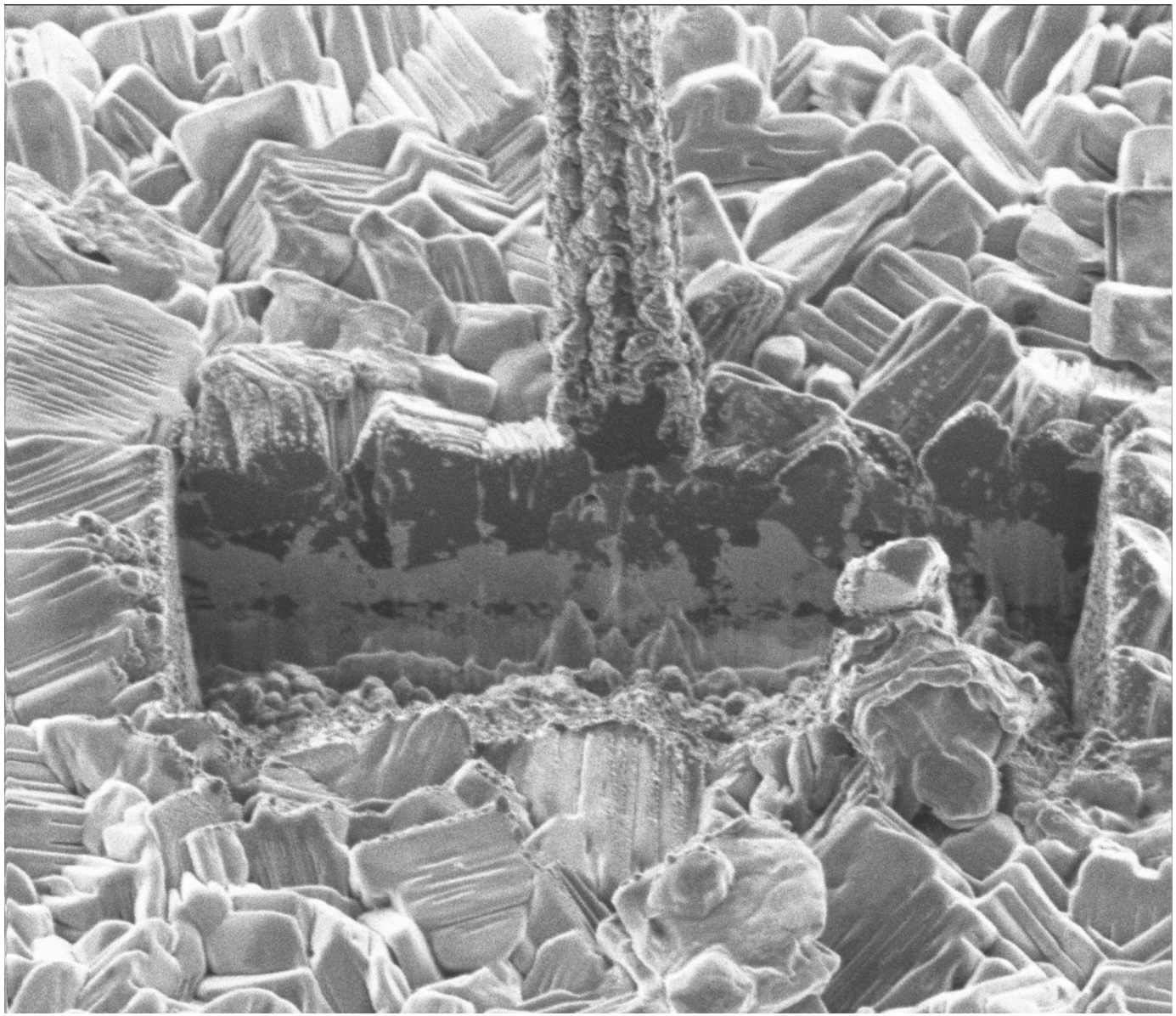
116 Days after Plating



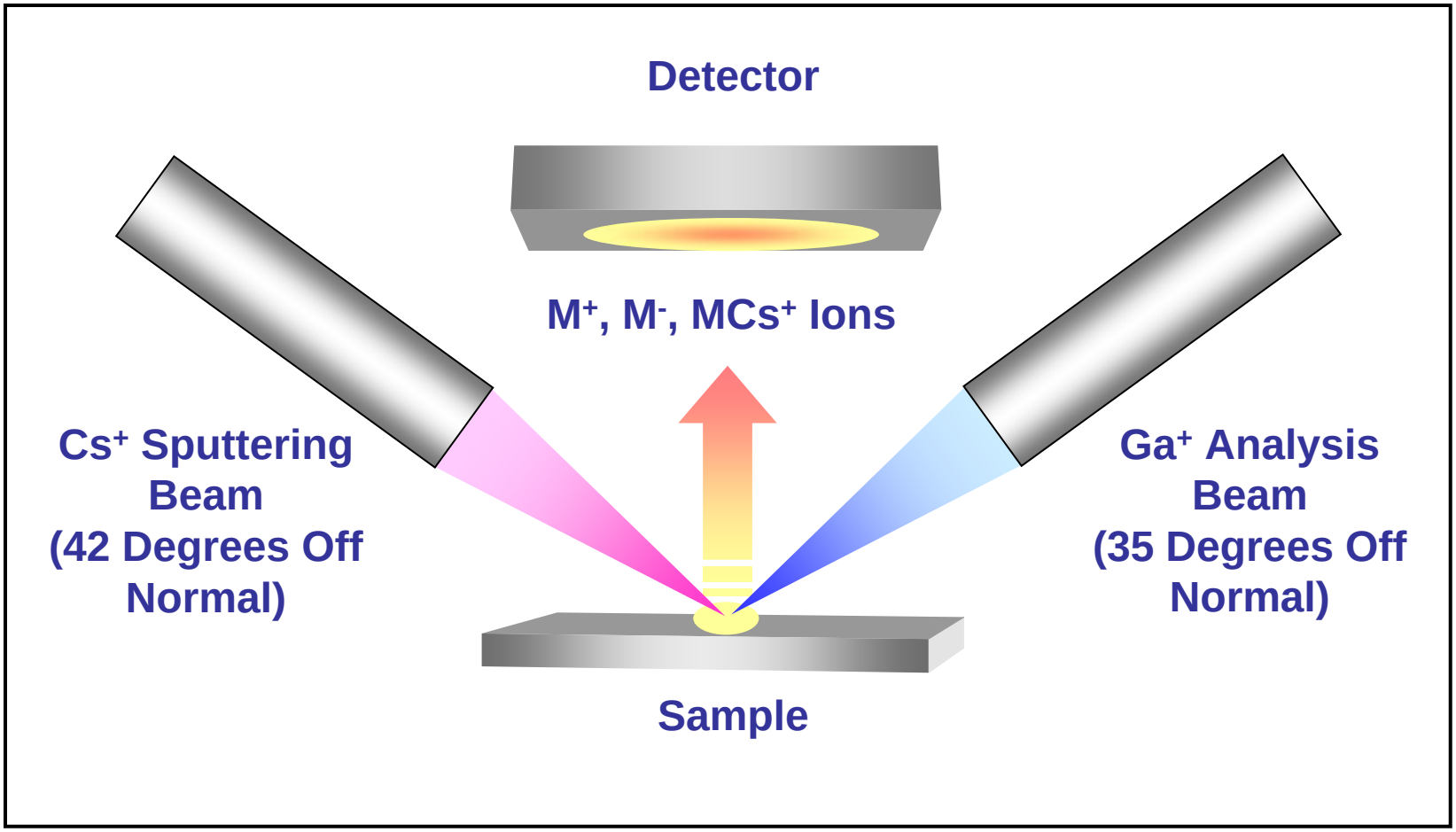
Whiskers Appear to Grow from Plating Surface (Matte Sn)



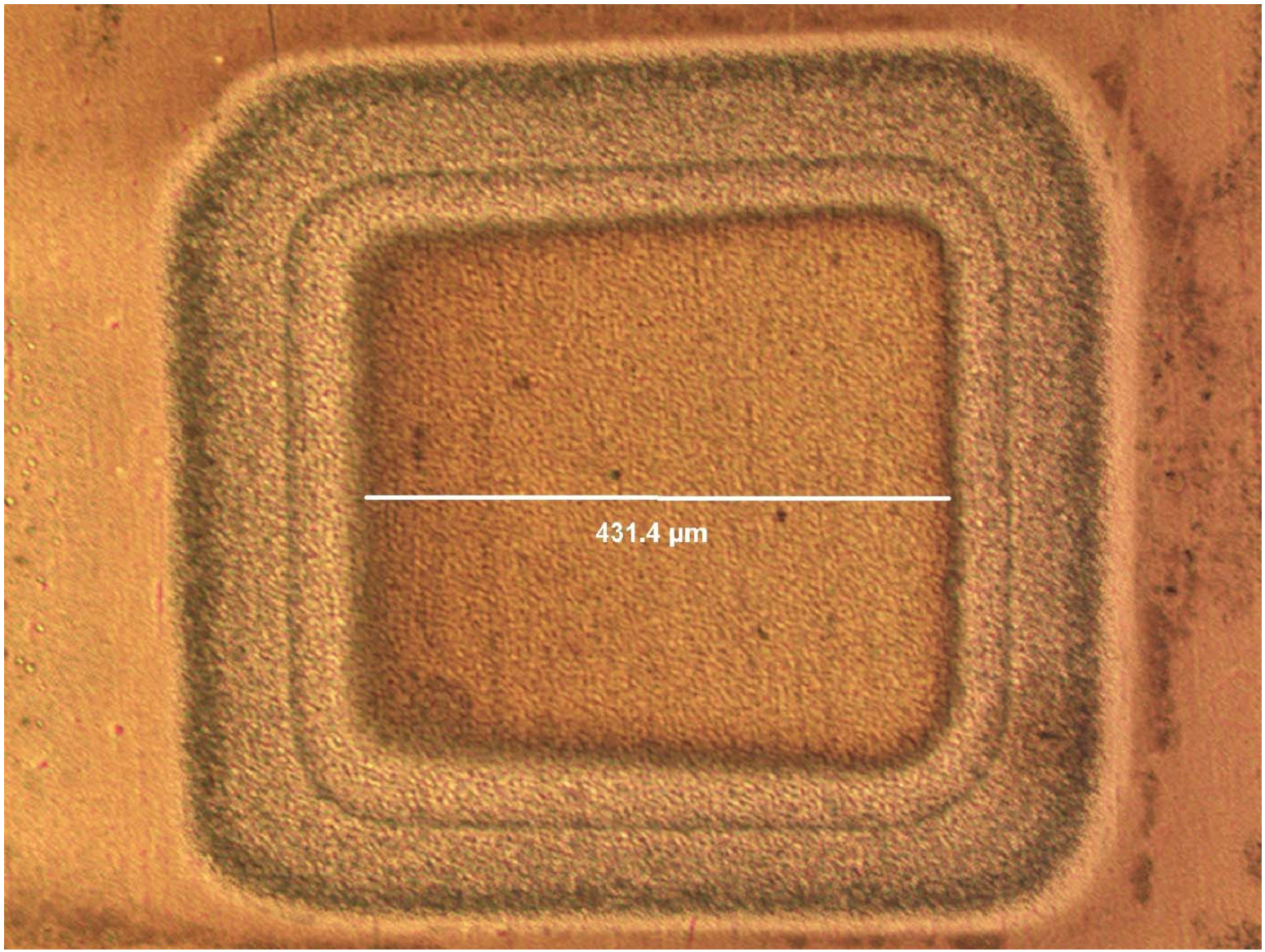
Whiskers Appear to Grow from Plating Surface (Matte Sn)



TOF-SIMS Spectrometer

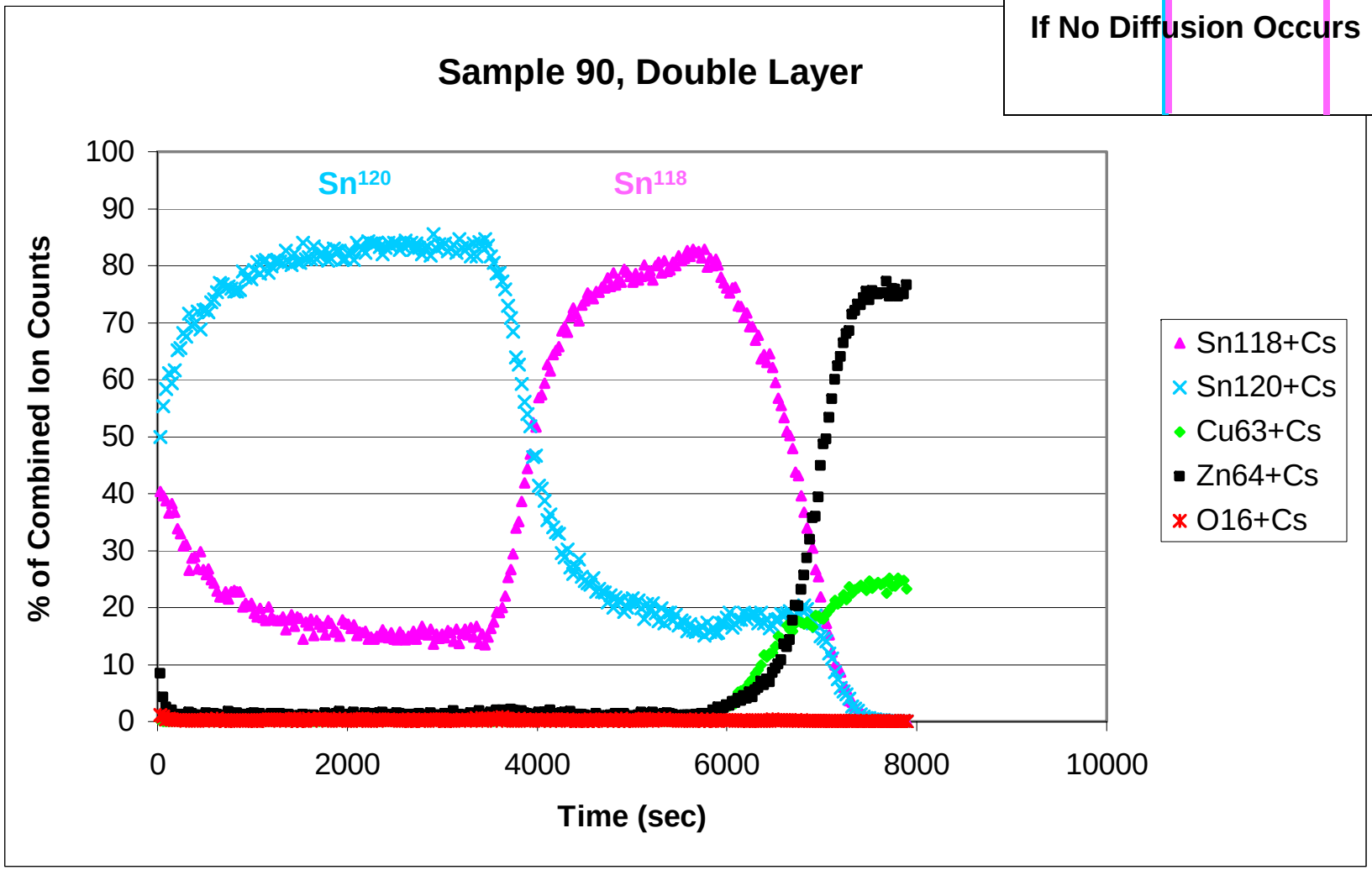


Typical Depth Profile Crater

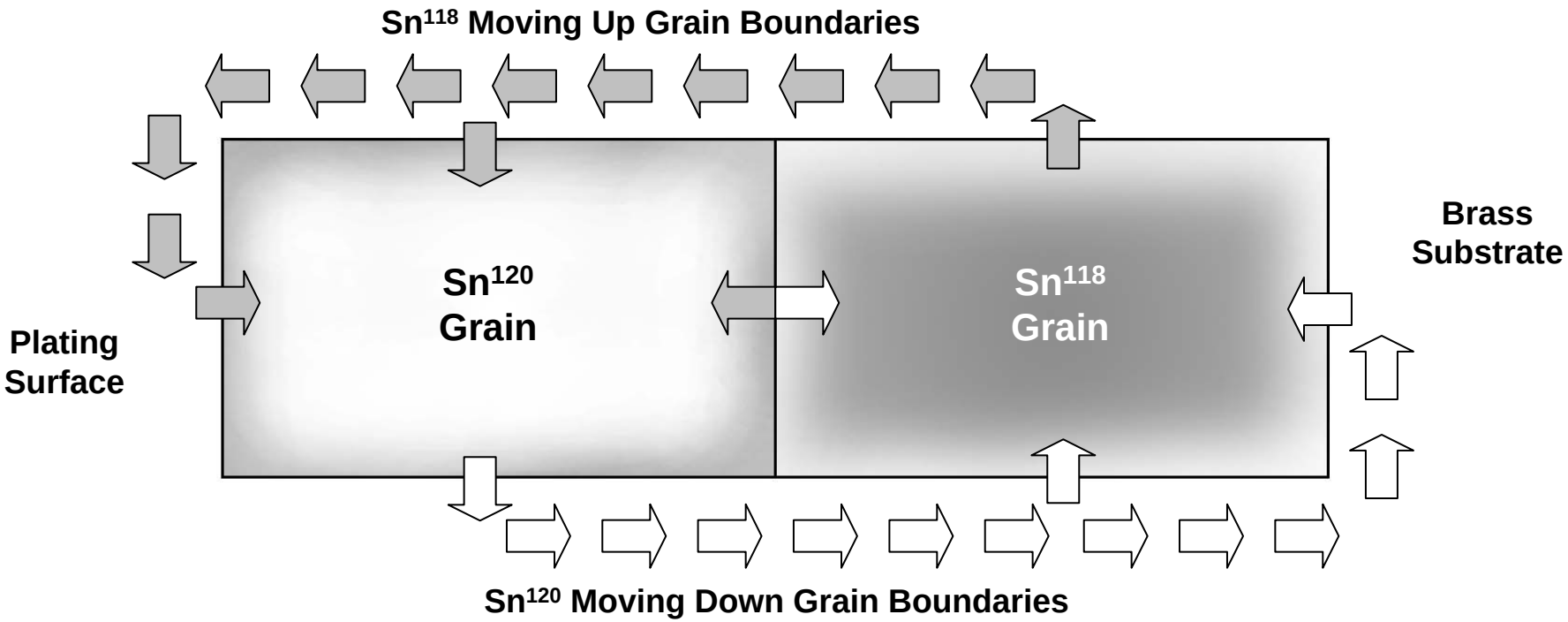


SIMS Depth Profile of a Bright Sn Double Layer

3 Days after Plating

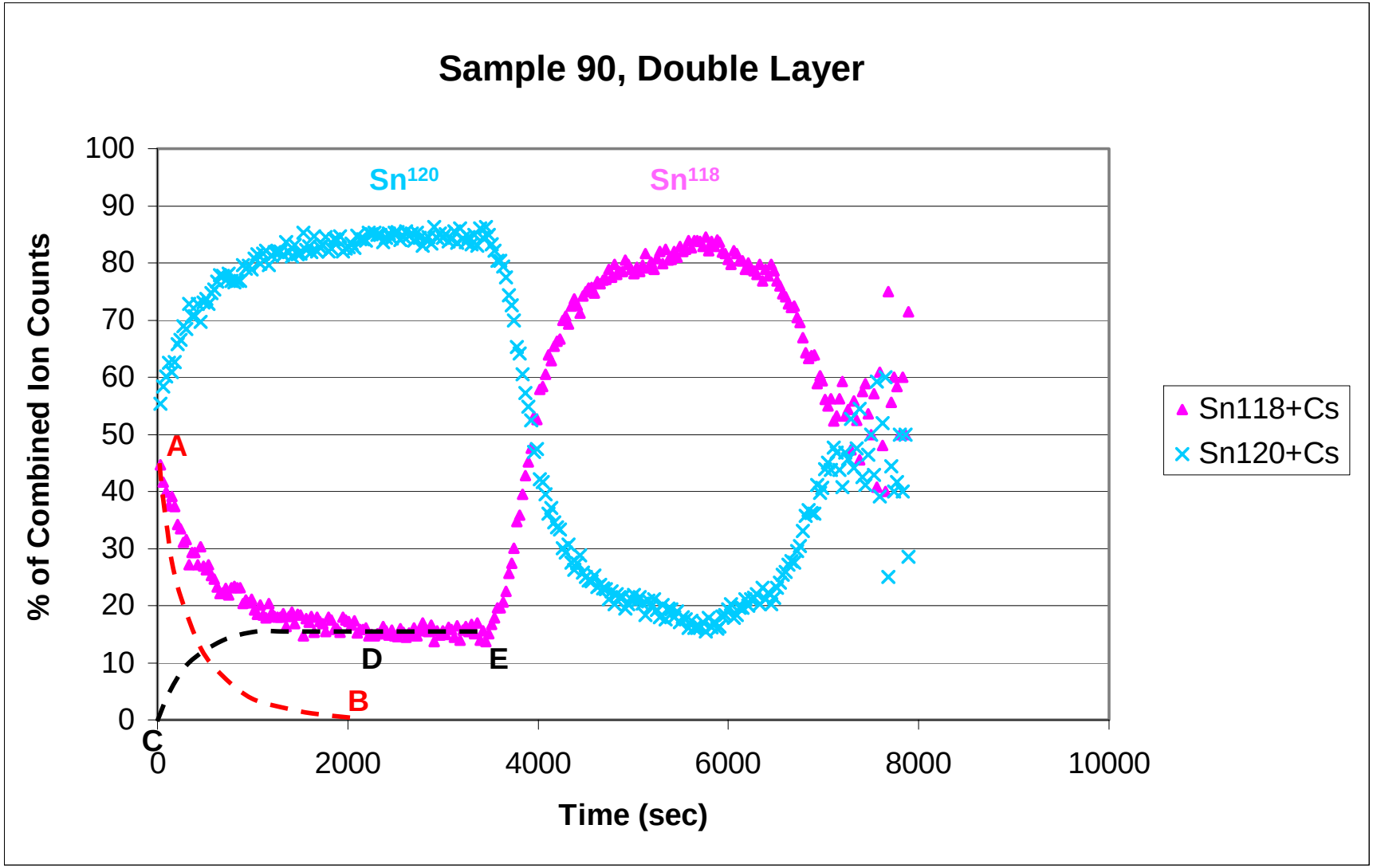


Sn^{118} Diffuses Up Grain Boundaries and onto the Surface
Sn^{118} then Diffuses from Surface Down into the Lattice



SIMS Depth Profile of a Bright Sn Double Layer Showing Sn Isotopes Only

3 Days after Plating

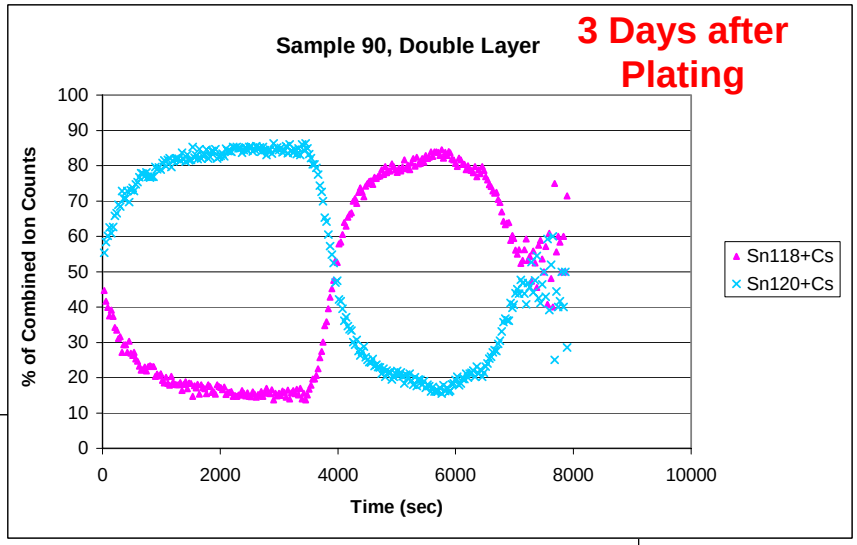


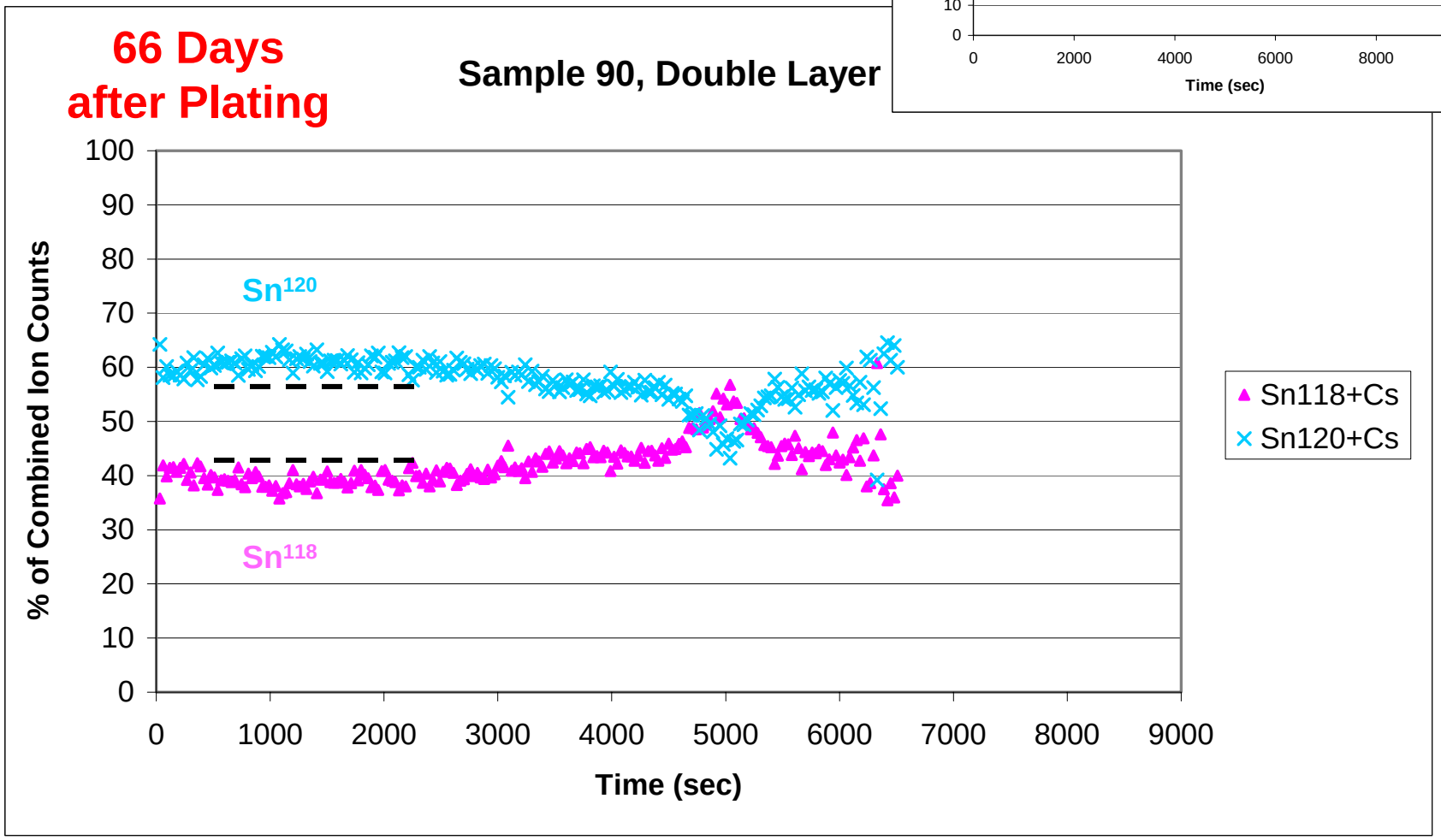
Assuming that the near surface concentration of Sn^{118} is relatively constant, Curve AB has the form of

$$\frac{c - c_o}{c_s - c_o} = 1 - erf\left(\frac{x}{2(D_t t)^{1/2}}\right)$$

Calculated a room temperature lattice diffusion coefficient of 10^{-15} cm^2/sec which is two to three orders of magnitude larger than the self-diffusion coefficient of tin (10^{-17} to 10^{-18} cm^2/sec at 25°C) as reported in the literature.

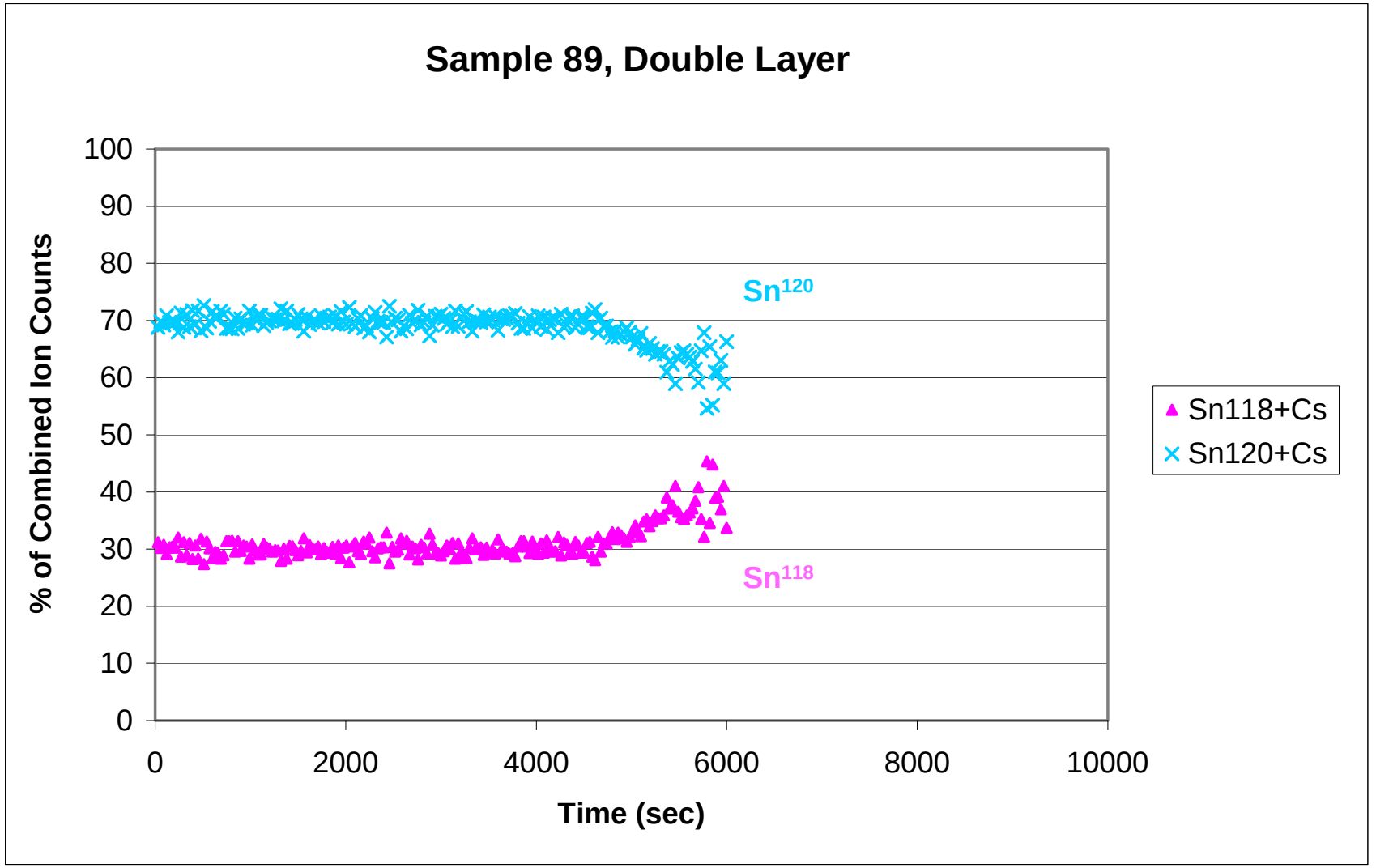
SIMS Depth Profile of a Bright Sn Double Layer



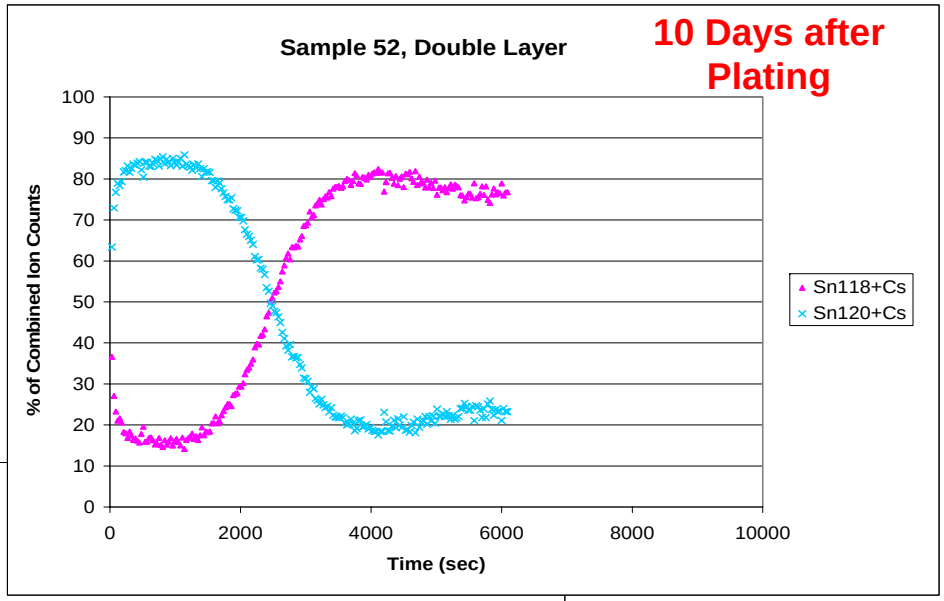


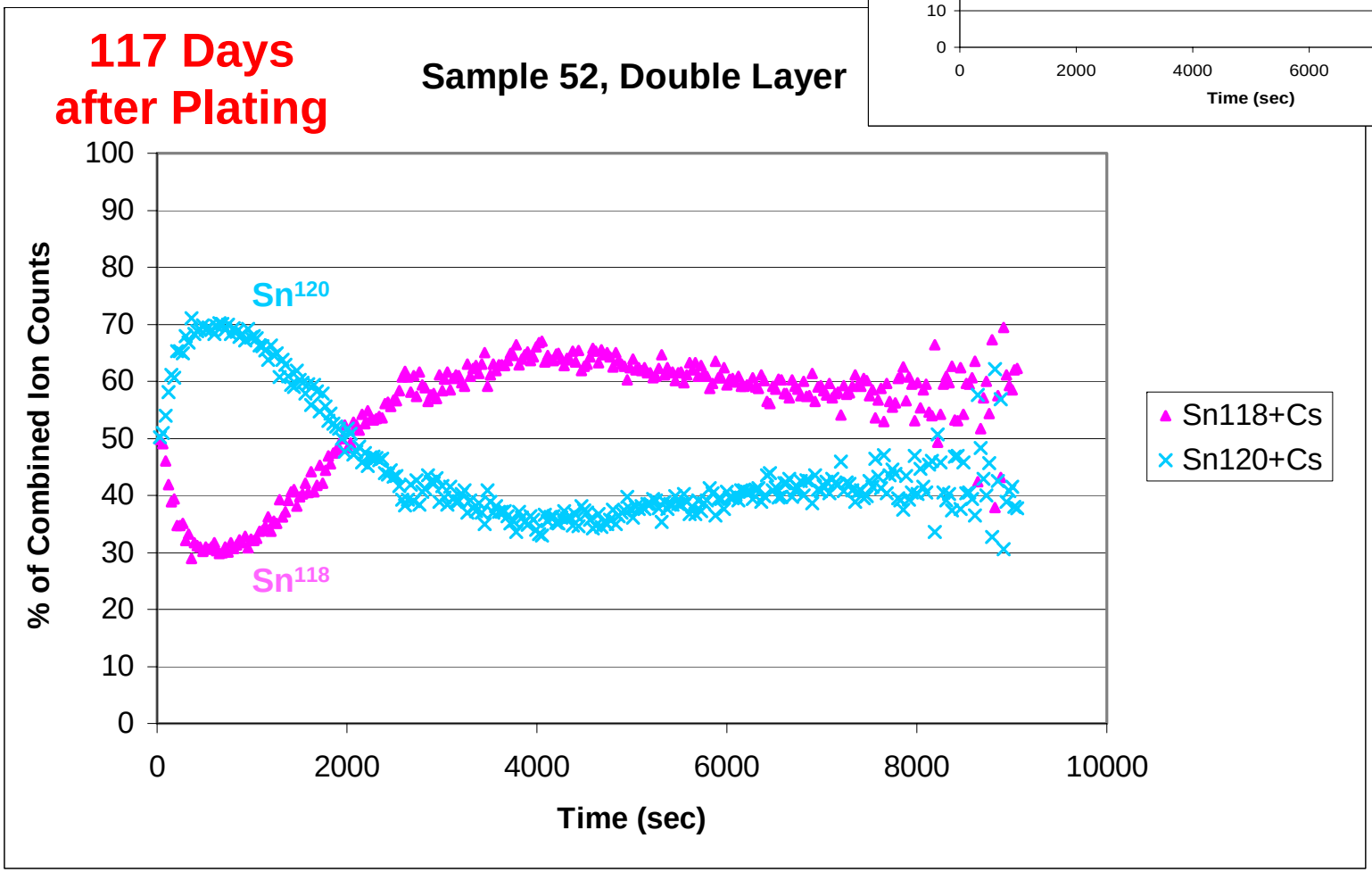
SIMS Depth Profile of a Second Bright Sn Double Layer

187 Days after Plating



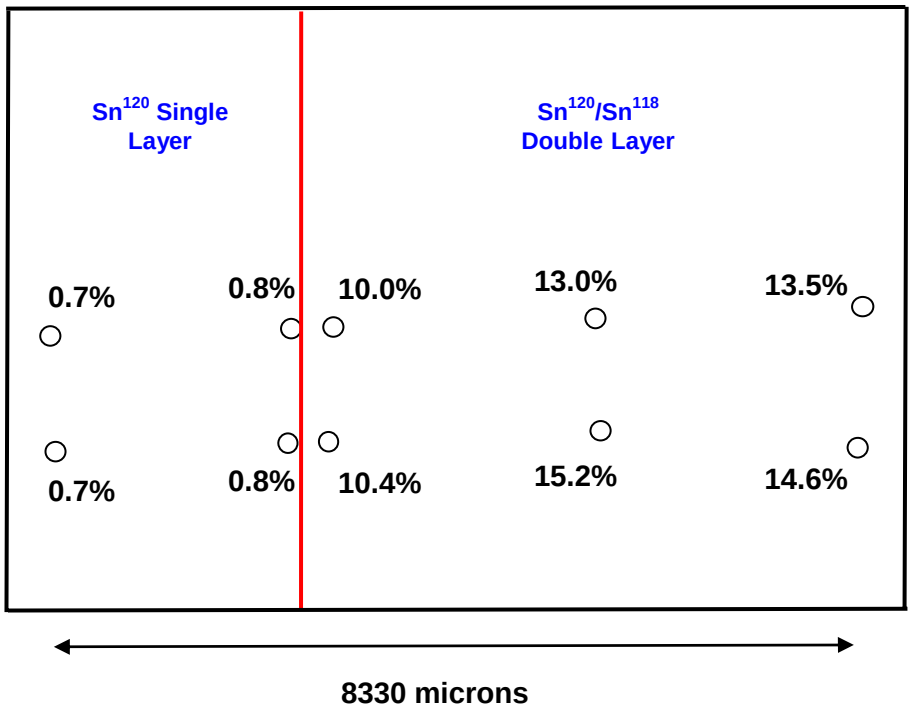
SIMS Depth Profile of a Matte Sn Double Layer



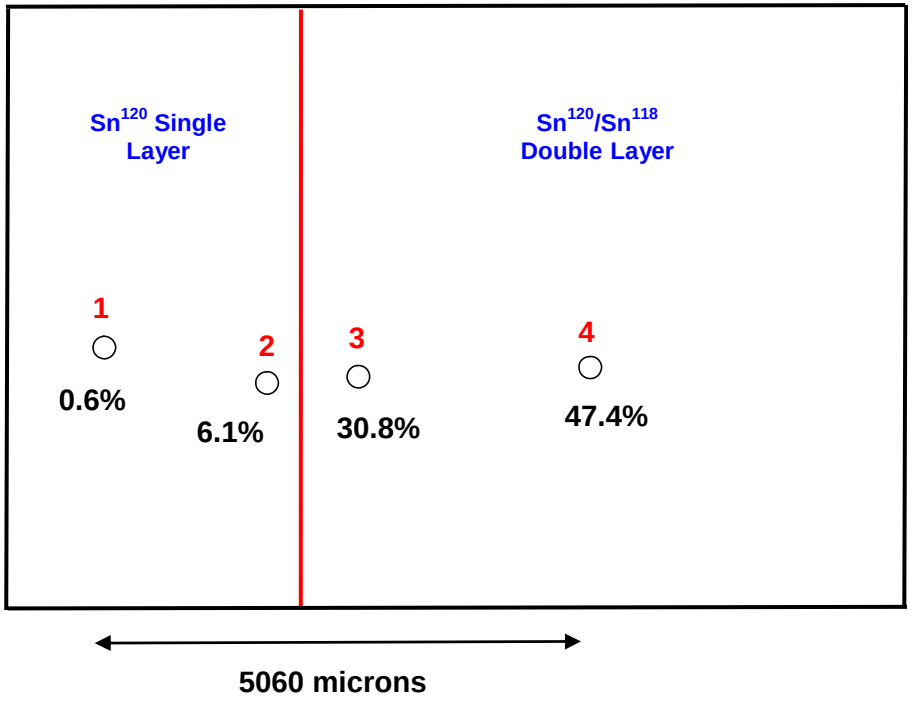


Spot Analyses on Bright Sn (Sample 91)

% Sn^{118} on Surface of Coupon
254 Days after Plating



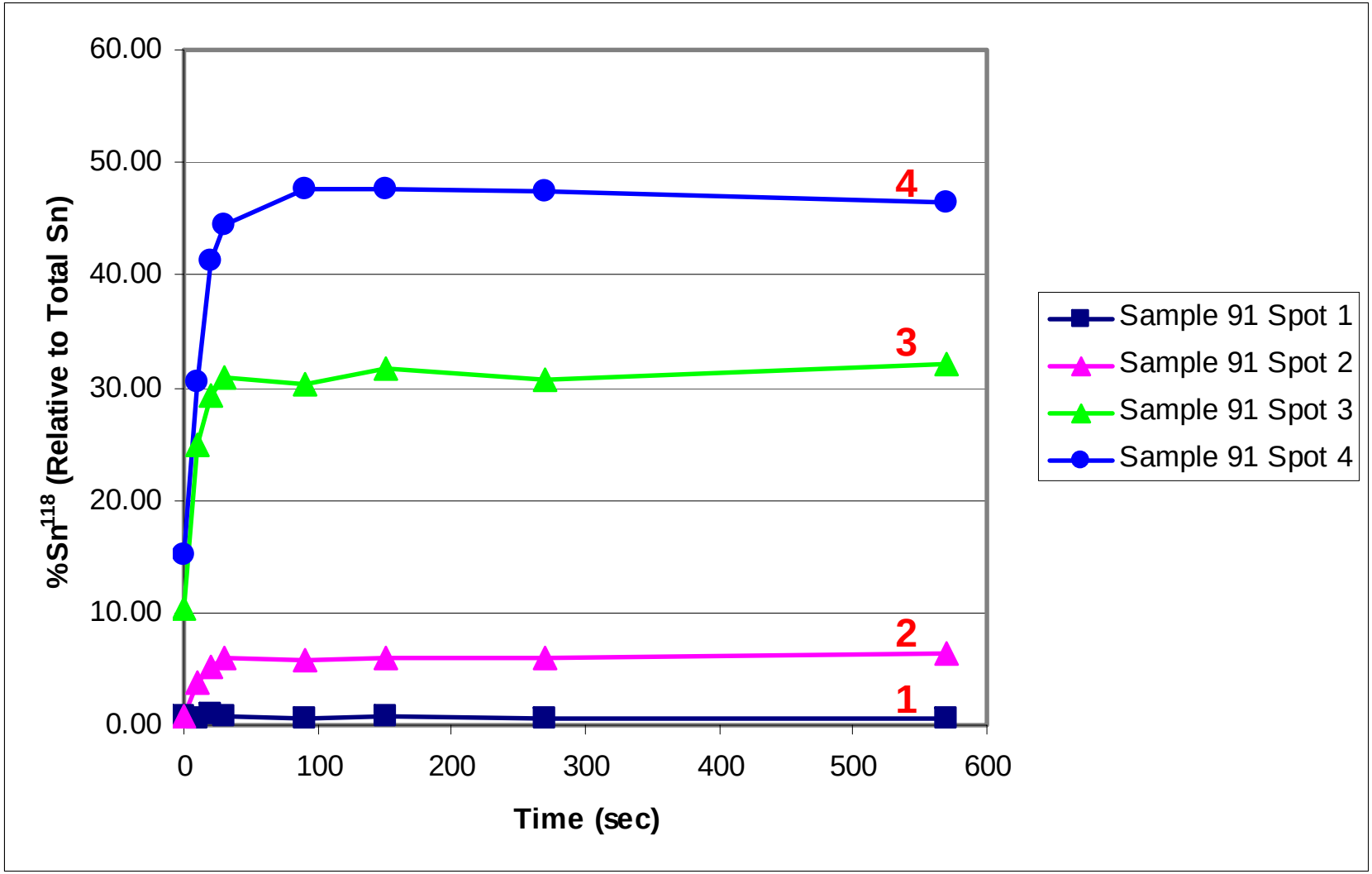
% Sn^{118} after 270 Seconds of Sputtering



- **Isotope composition "frozen" on surface (by an oxide layer?)**

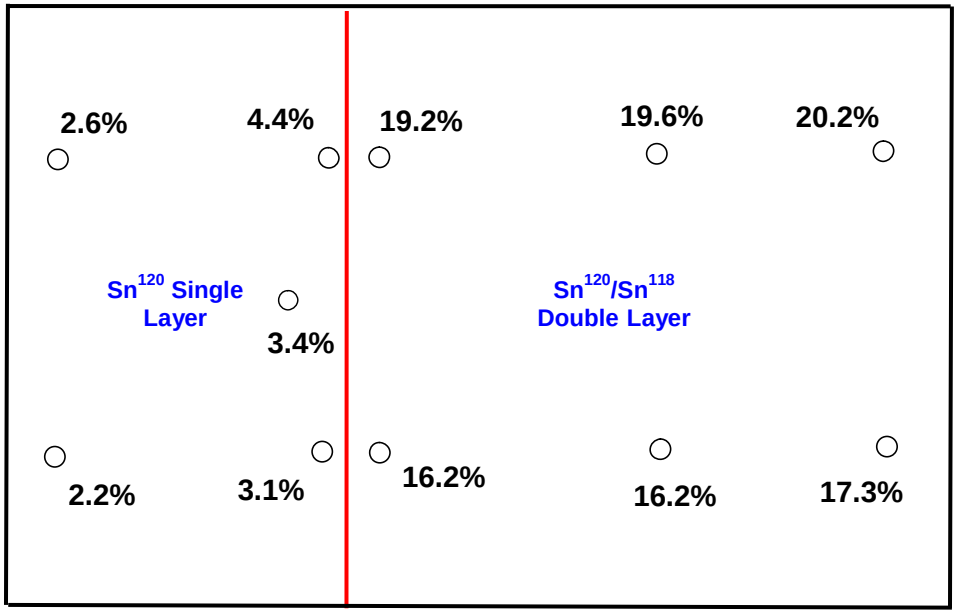
Spot Analyses on Bright Sn (Sample 91)

(% Sn^{118} vs. Sputter Time)



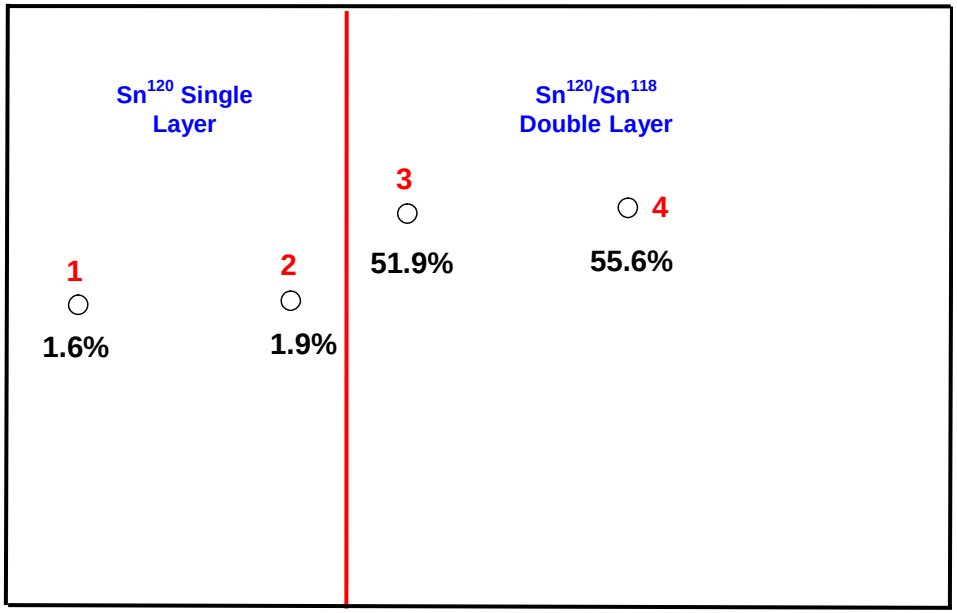
Spot Analyses on Matte Sn (Sample 63)

% Sn^{118} on Surface of Coupon
299 Days after Plating



8730 microns

% Sn^{118} after 270 Seconds of Sputtering



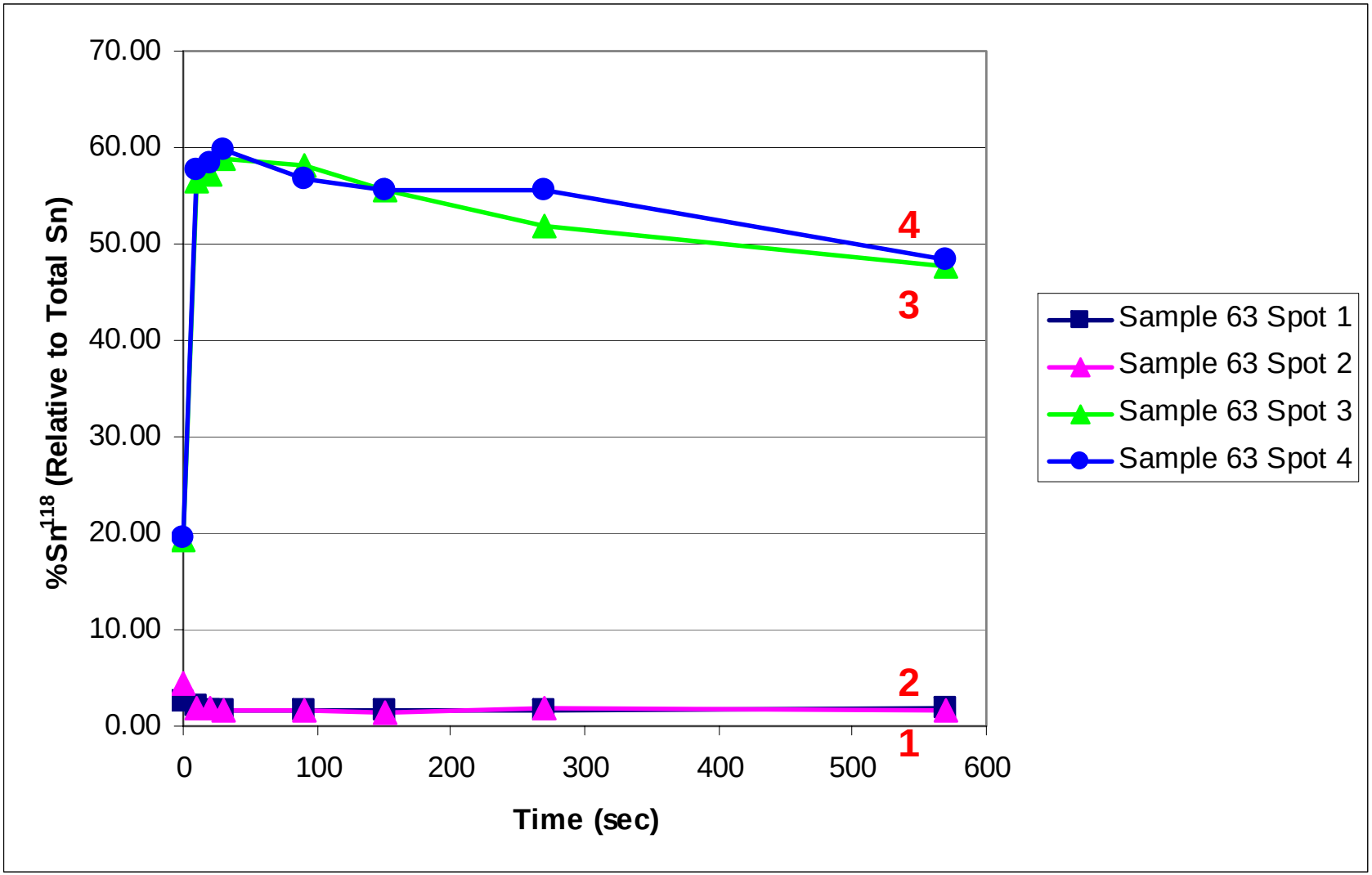
5840 microns

- Long range diffusion of Sn^{118} observed parallel to substrate
- Larger quantities of Sn^{118} on surface vs. in lattice suggests diffusion occurred through grain boundaries

- Isotope composition "frozen" on surface (by an oxide layer?)

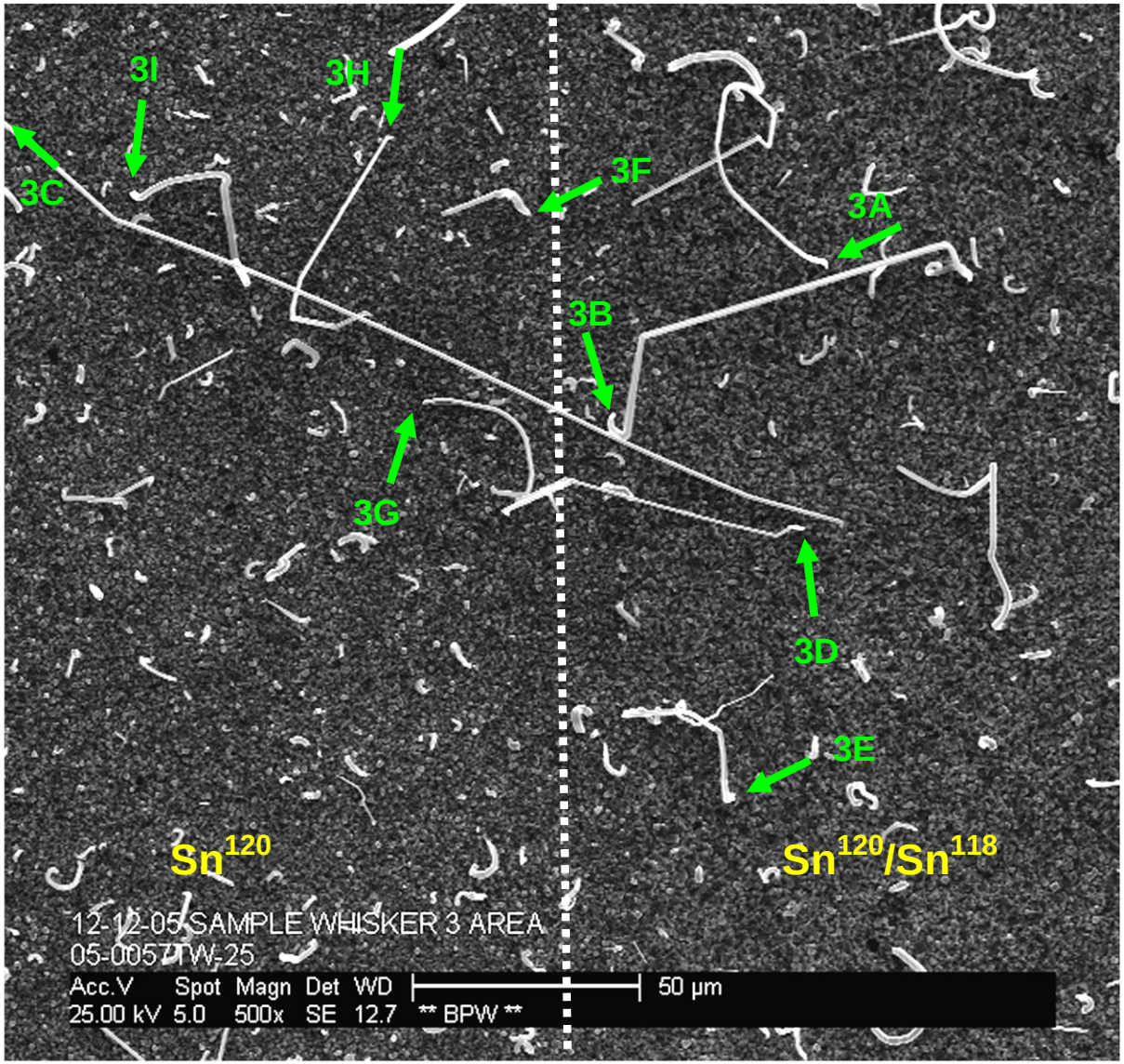
Spot Analyses on Matte Sn (Sample 63)

(% Sn^{118} vs. Sputter Time)

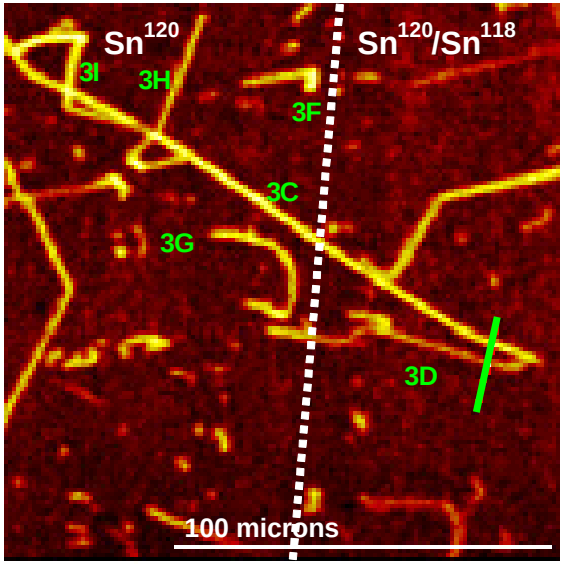


Whiskers on Both Sides of a Matte Sn Single Layer/Double Layer Interface

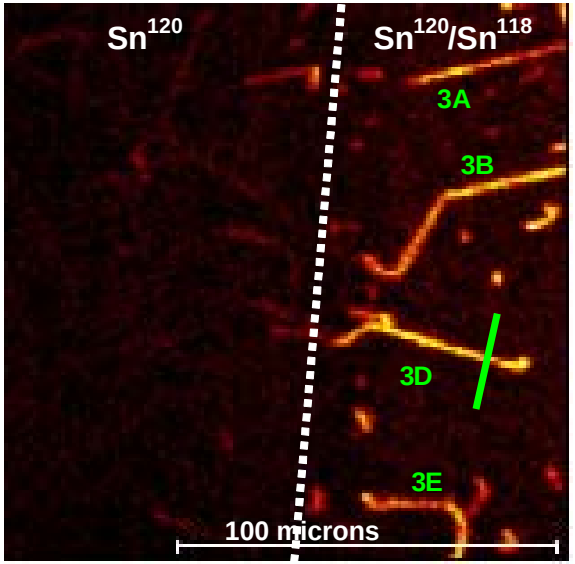
Green Arrow Marks Whisker Base

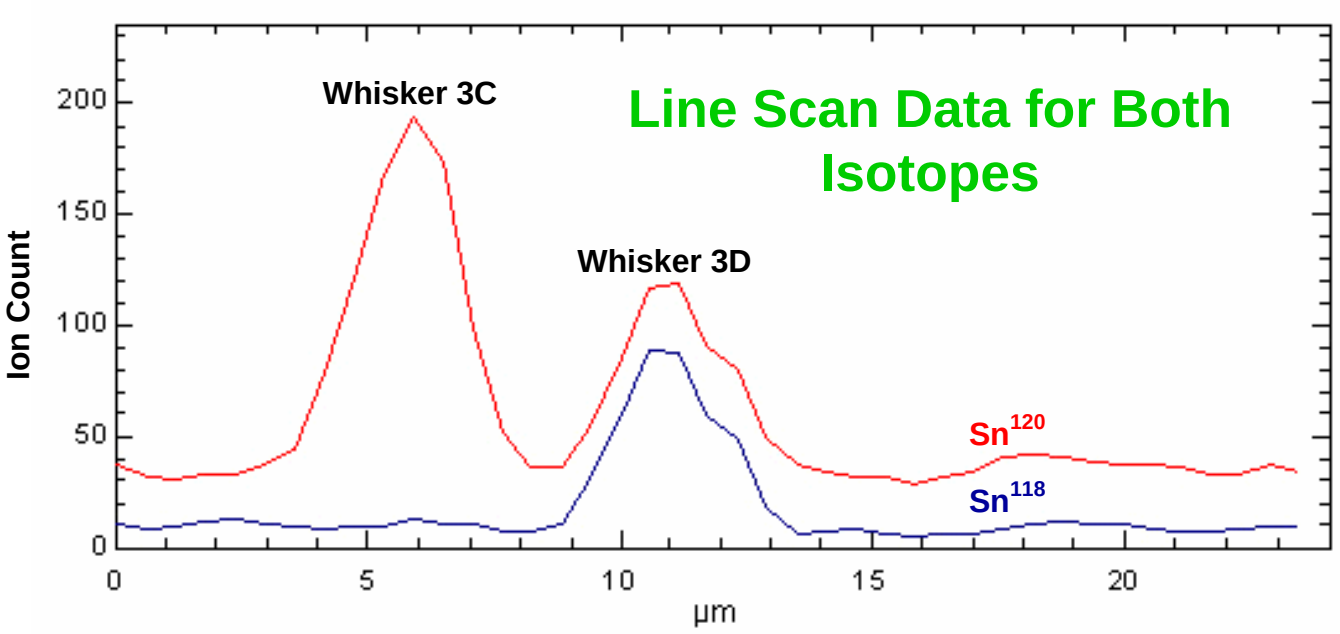


Sn^{120} SIMS Ion Image



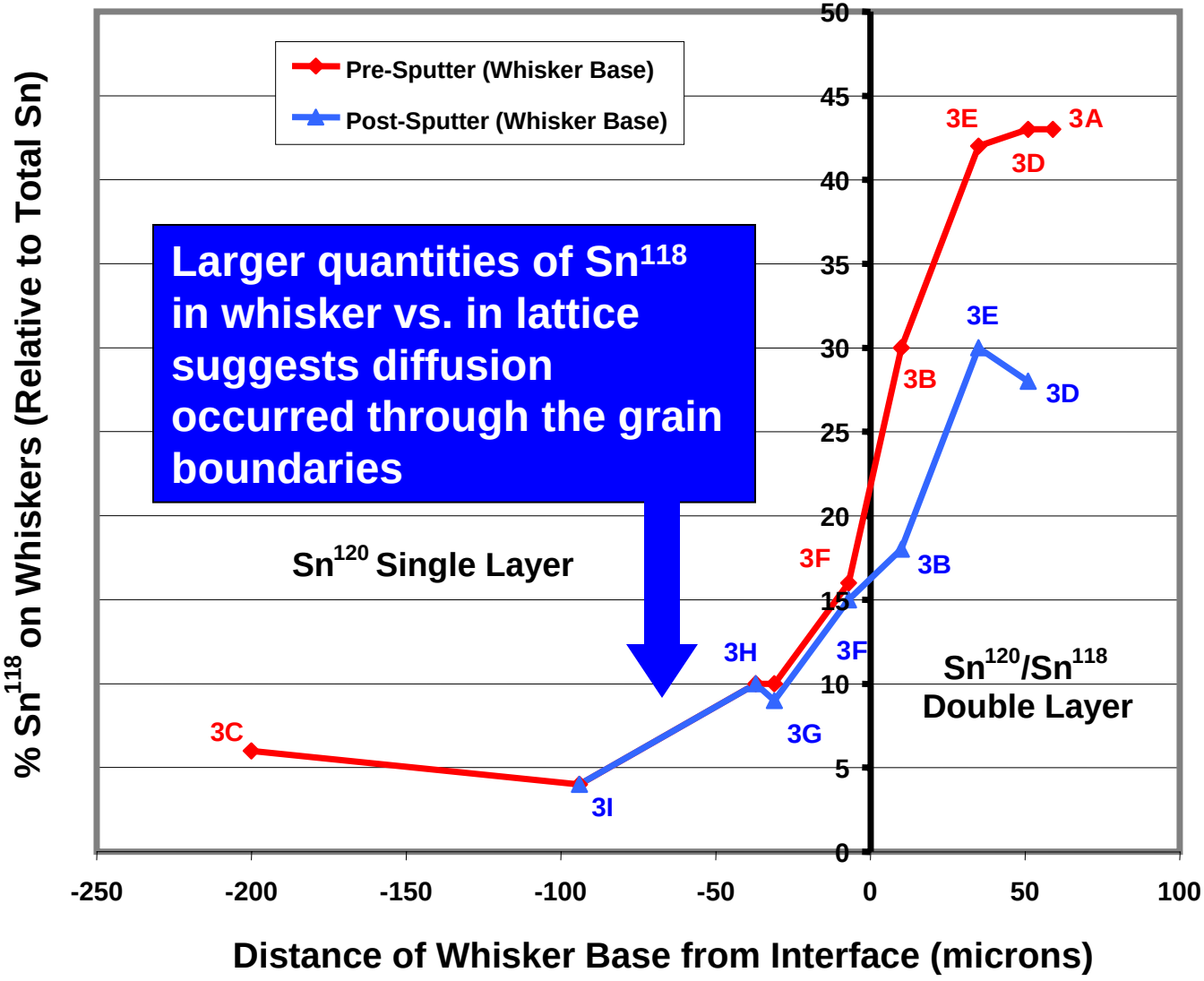
Sn^{118} SIMS Ion Image



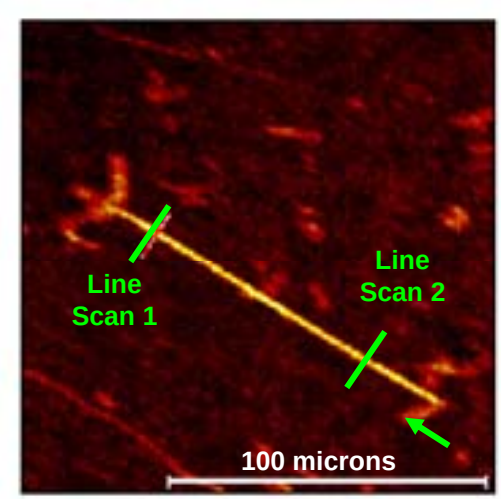


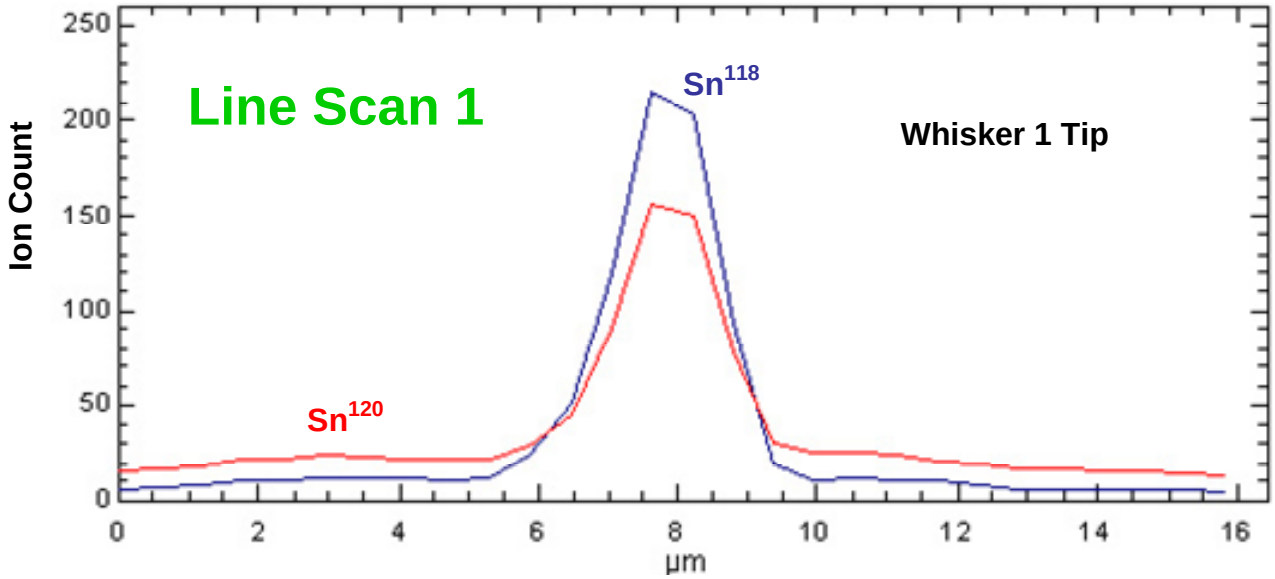
Isotopic Composition of Whiskers on Both Sides of a Matte Sn Single Layer/Double Layer Interface

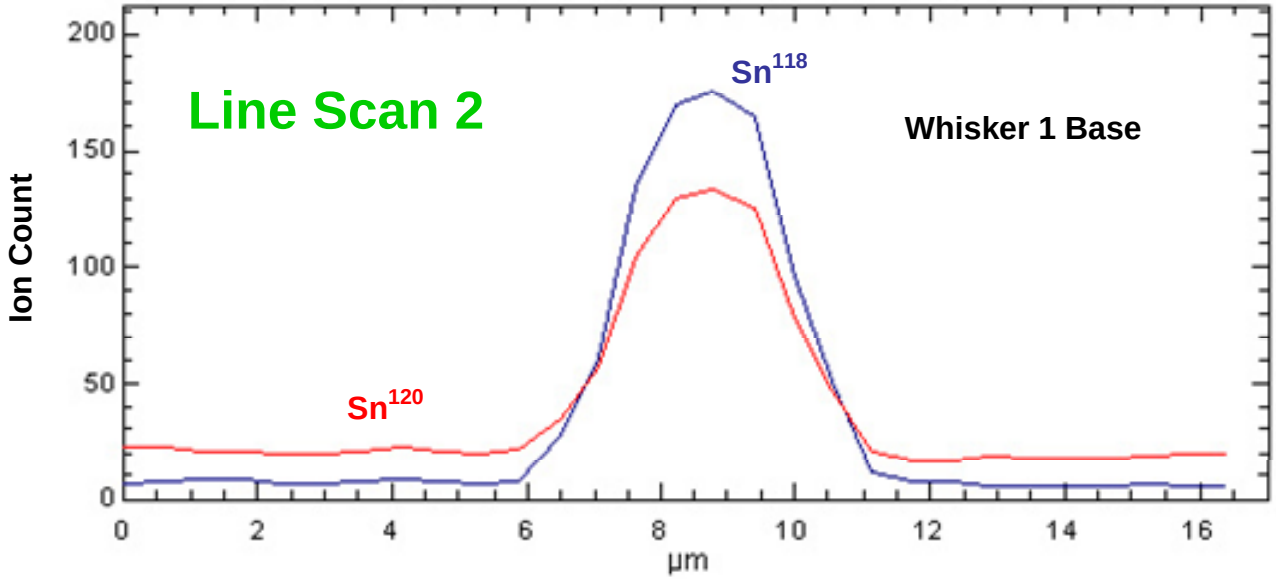
(Before Sputtering and After Sputtering)



Isotopic Composition of a Whisker Centered on a Matte Sn Double Layer

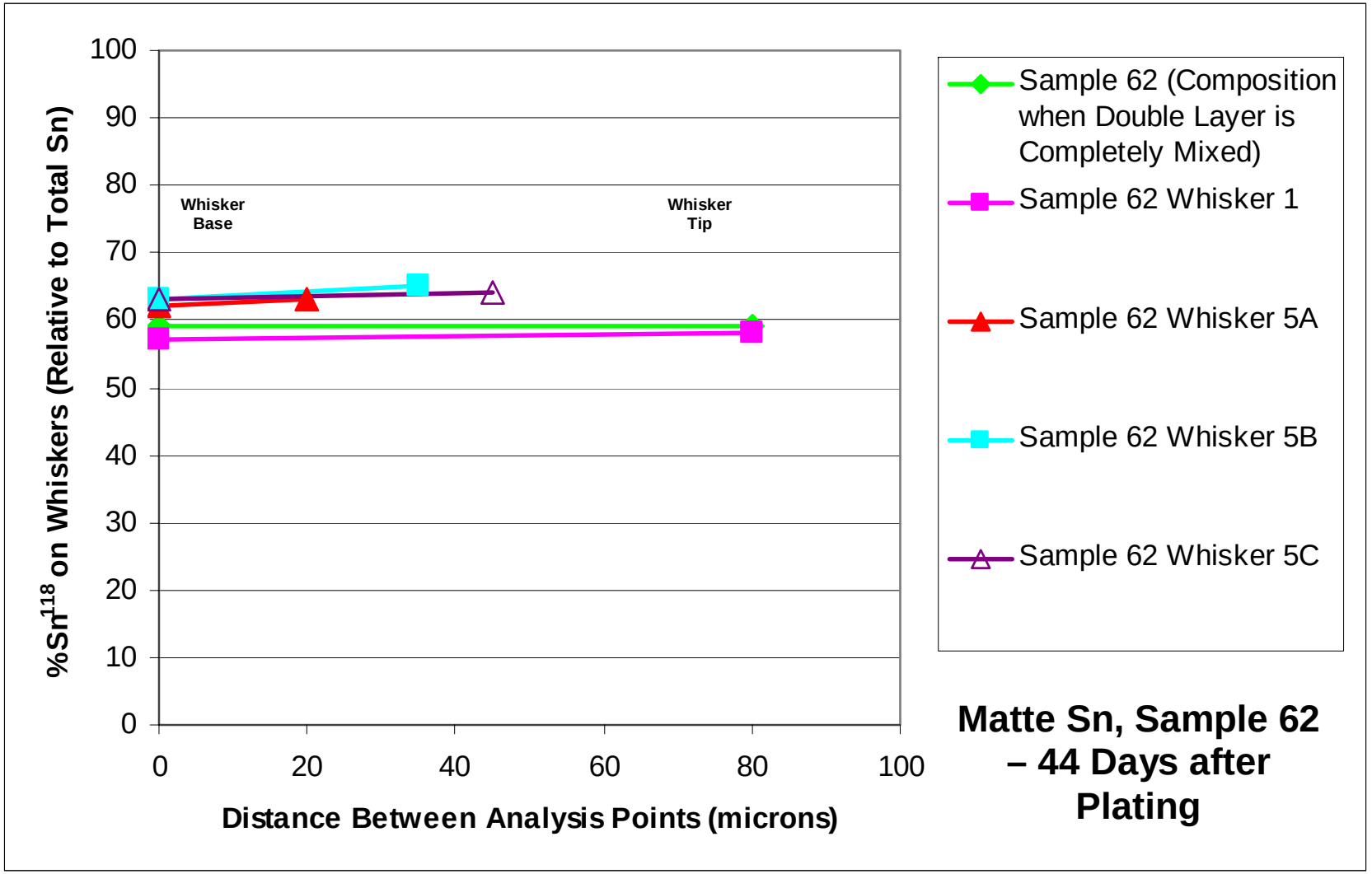






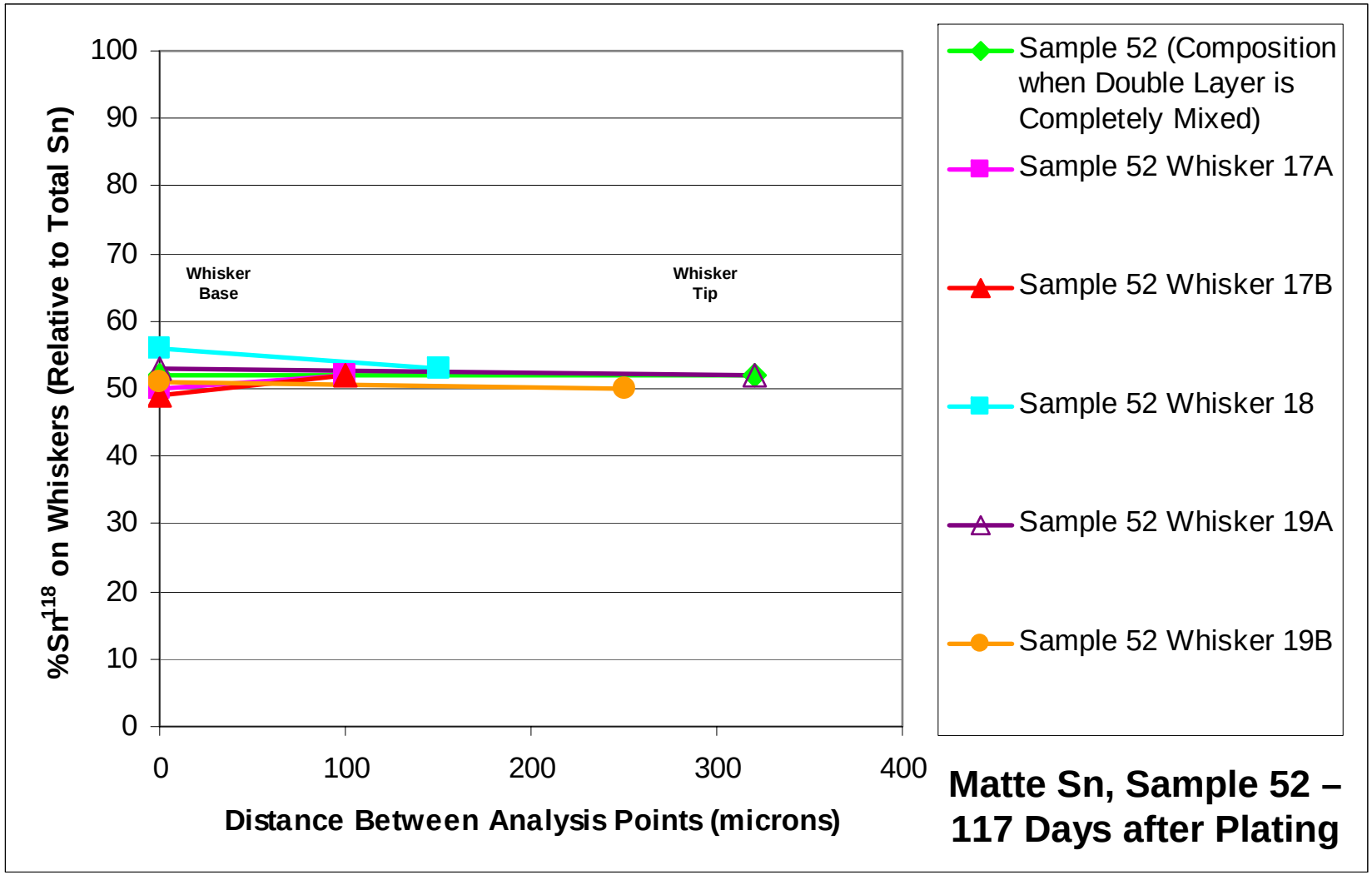
Isotopic Composition is Constant from Base to Tip of Whisker

(Matte Sn Double Layer; Double Layer is not Mixed Yet)



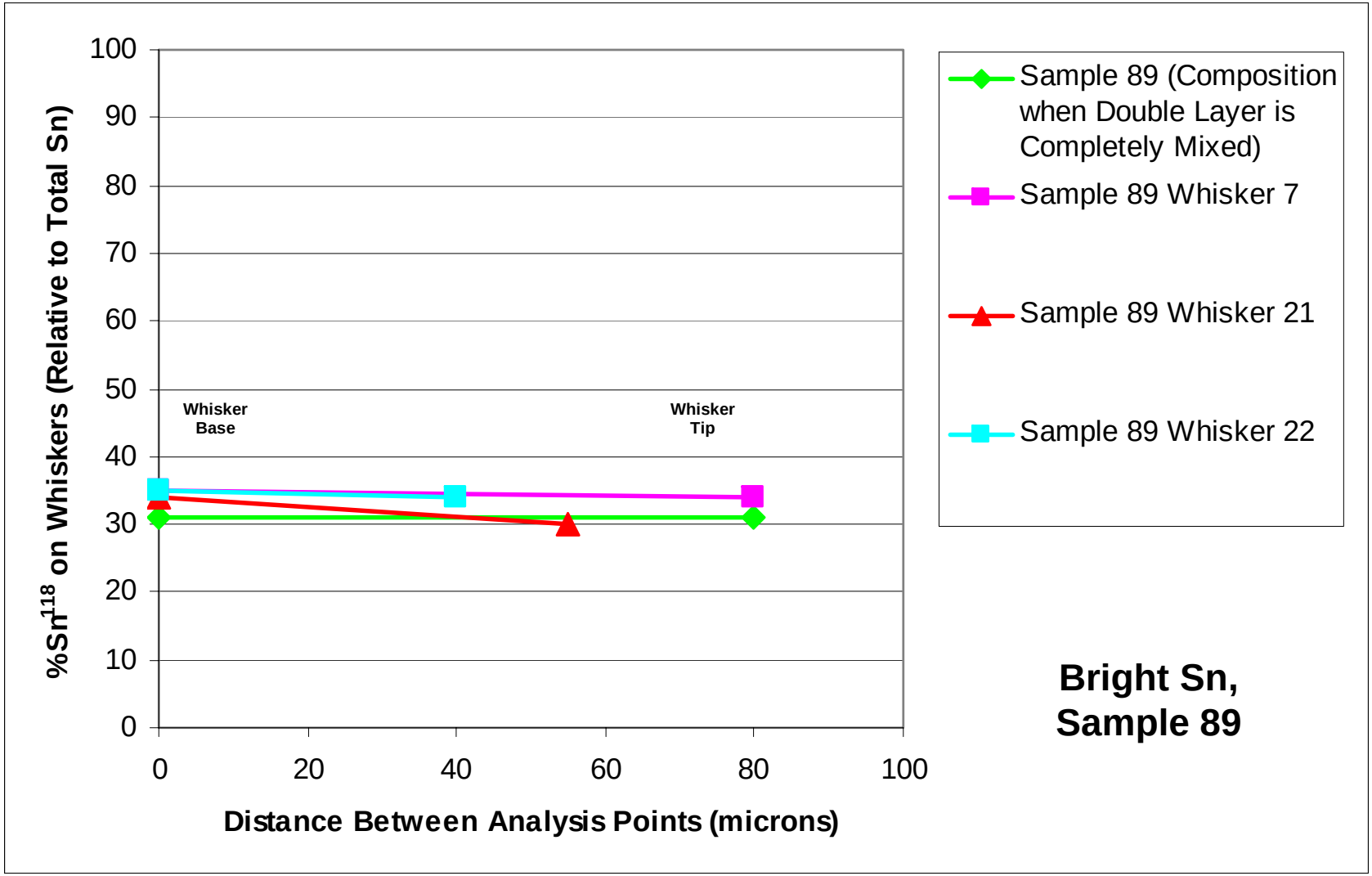
Isotopic Composition is Constant from Base to Tip of Whisker

(Matte Sn Double Layer; Double Layer is not Mixed Yet)

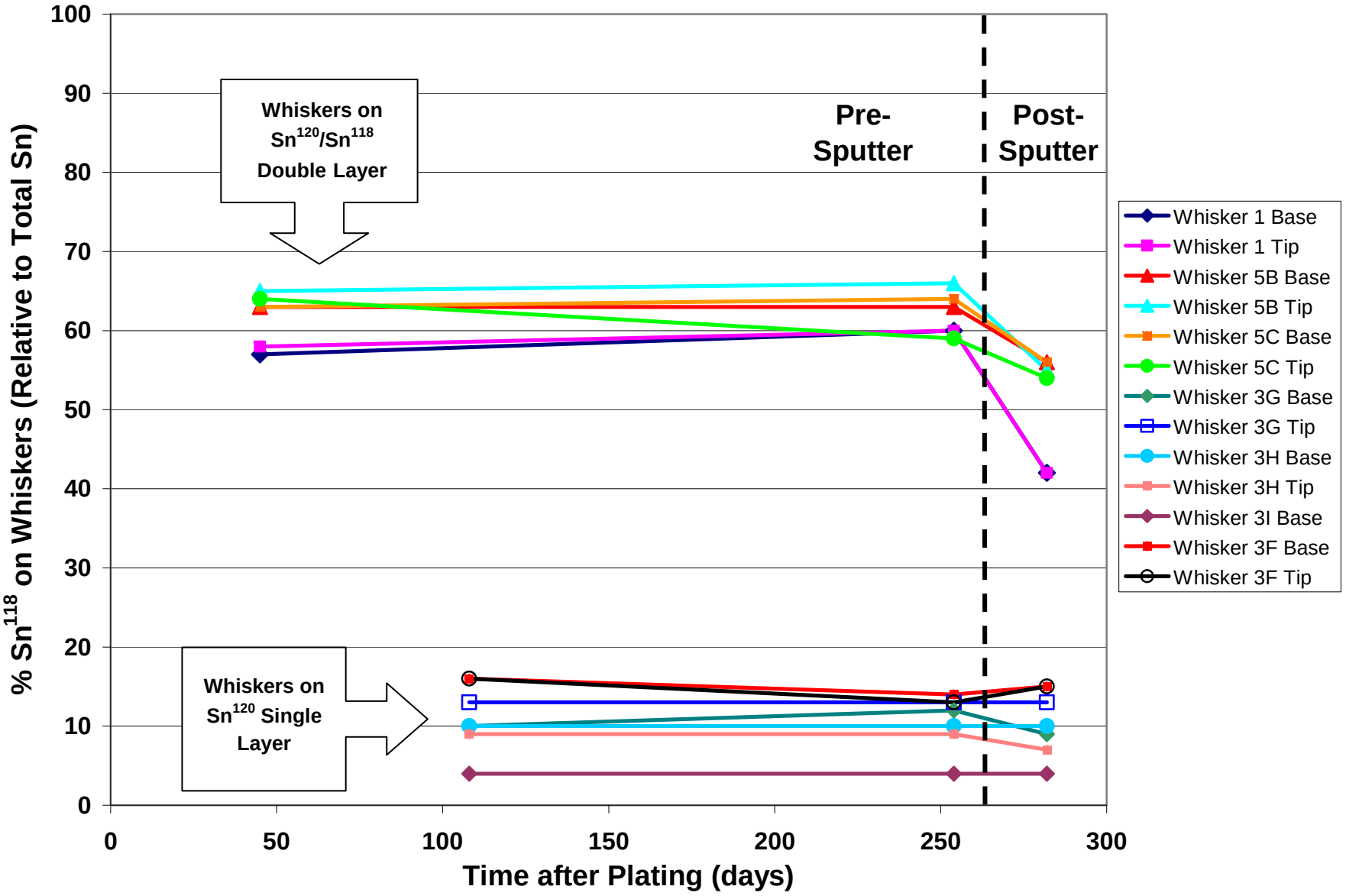


Isotopic Composition is Constant from Base to Tip of Whisker

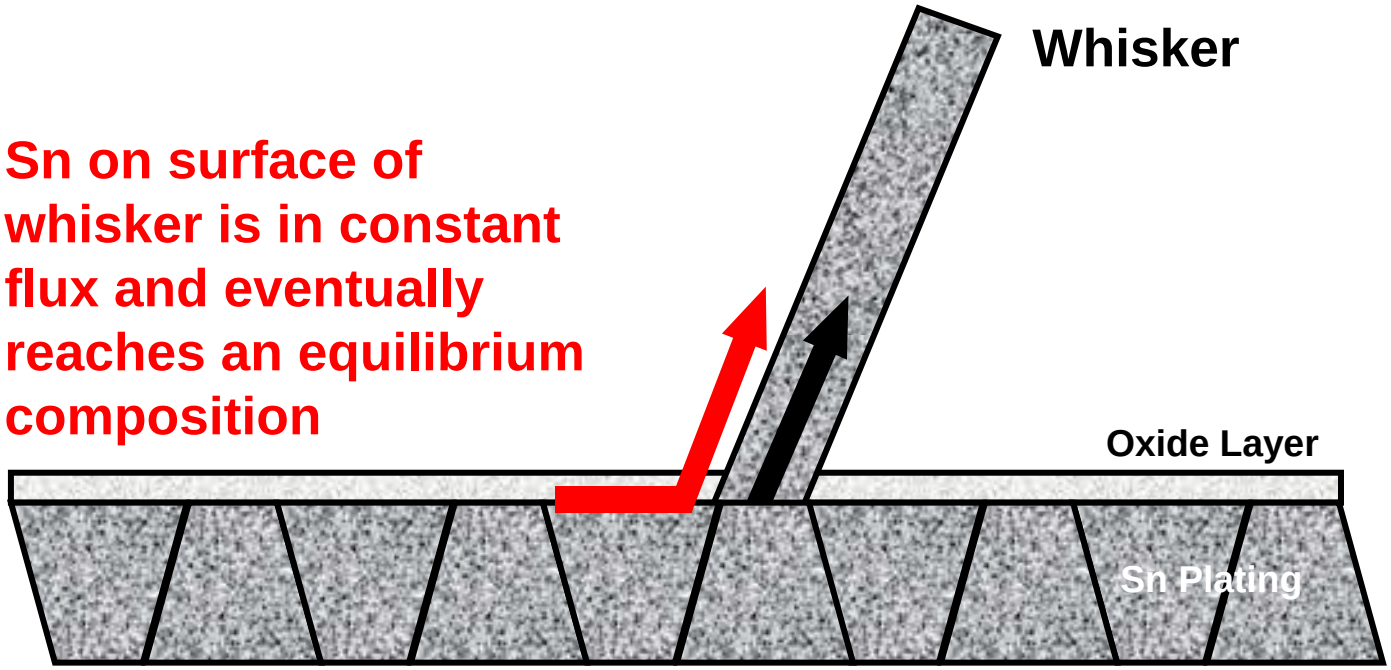
(Bright Sn Double Layer)



Isotopic Composition of Whiskers on Matte Sn before and after Sputtering (Sample 62)



- **The isotopic composition of the interior of a whisker on matte Sn can be different from the exterior composition**



Step 1. Sn in grain boundaries feeding whisker has not reached an equilibrium isotopic composition when whisker forms (i.e., it is Sn^{120} rich)

Conclusions

- Whiskers grew from grains on the surface of the matte Sn and from recrystallized nodules on the bright Sn
- Interdiffusion of the isotope layers perpendicular to the substrate was fast (grain size was unchanged during mixing)
- Long range diffusion of the isotopes parallel to the substrate did occur
- Diffusion was through the grain boundaries
- Isotopic compositions were frozen on the surfaces of the platings (by an oxide layer?)
- The isotopic composition of the interior of a whisker on matte Sn can be different from the exterior composition